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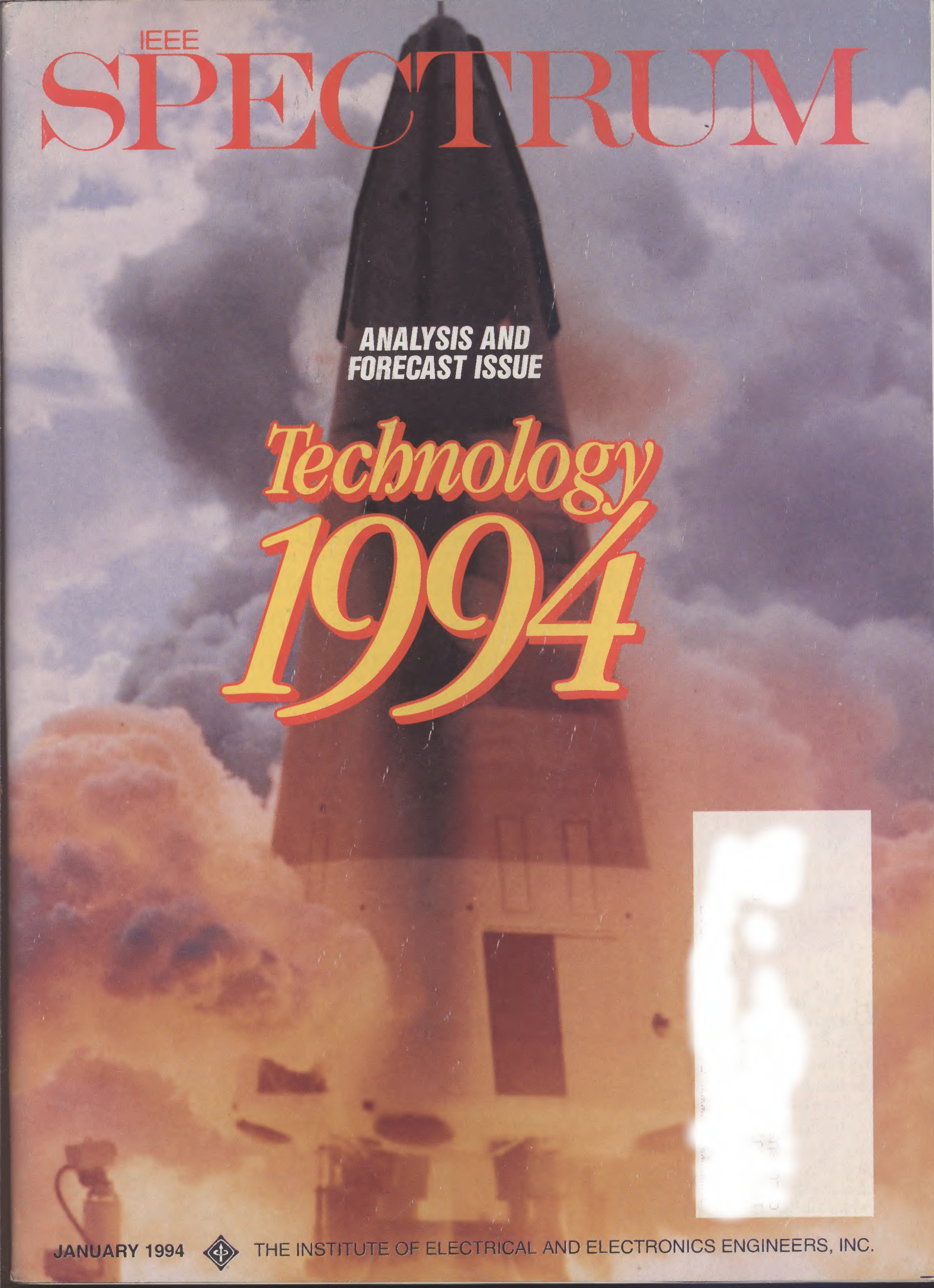

ANALYSIS AND FORECAST ISSUE

Technology 1994

JANUARY 1994 THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

Newslog

NOV 11. The **National Aeronautics and Space Administration**, Washington, D.C., said it had completed the first phase of a program to build a **supersonic airliner** that could replace the aging Anglo-French Concorde and would begin the second. The first phase evaluated environmental considerations while the second will develop the airframe, propulsion, and systems technologies over seven years at a cost of US $1.2 billion. The aircraft, planned to enter service early in the next century, will have twice Concorde's 5600-km range and carry twice as many passengers.

NOV 11. Pacific Telesis Group, San Francisco, said it would spend $16 billion over seven years to build a high-speed information superhighway in California. The network will reach 1.5 million homes within three years and 5 million by the year 2000. The company said the network will use $5 billion in equipment and technical services from **AT&T Co.**

NOV 15. AT&T Microelectronics, Berkeley Heights, N.J., and **NEC Corp.**, Tokyo, said they had agreed to develop a process for manufacturing ICs with features as small as 0.25 μm, halving the size attainable using today's most advanced commercial IC technologies. The pact is based on the success of the companies' 1991 effort to develop a common 0.35-μm process, which will be used to mass produce 0.35-μm CMOS chips by mid-1995.

NOV 15. Scientific Atlanta Inc., Norcross, Ga., announced that it had developed a device for making phone calls over cable-television systems. Called the CoAccess Network, the unit lets users make calls while receiving faxes and order interactive games and pay-per-view movies over cable wires. The following week, **Jones Intercable Inc.** and **MCI Communications Corp.** said they would test the new product in Alexandria, Va., and Chicago.

NOV 16. National Power of Britain and India's **Ashok Leyland** said they would jointly take a 51 percent stake in a UK £684 million project for a 1000-MW coal-fired plant at Visakhapatnam in the Indian state of Andhra Pradesh. Analysts said the move suggests that foreign groups are beginning to overcome the regulatory and other hurdles that have restricted entry into the Indian power industry.

NOV 17. MCI Communications Corp., Washington, D.C., said it had signed agreements with four wireless-technology companies and **Lincoln Laboratory**, Cambridge, Mass., to develop personal communications services using novel wireless phone devices. MCI said the group will establish specifications for U.S. systems that would be compatible with the global system for mobile communications (GSM) platform developed in Europe.

NOV 22. Mitsubishi Electric Corp., Tokyo, said it had developed two large-capacity thyristors using 15-cm silicon wafers, halving the number of thyristors required in any given application. One model is a photothyristor that has an 8-kV, 4-kA capacity, making it over five times more powerful than existing 10-cm wafer thyristors. The second is a gate-turnoff thyristor with a 6-kV, 6-kA capacity, twice that of existing products.

NOV 22. Japan's Federation of Electric Power Companies said that construction of a fast-breeder reactor, which can turn spent uranium into usable plutonium while producing electricity, may start early next century, instead of in the late 1990s as scheduled. The postponement is due in part to Western nations' increasingly cautious attitude toward the use of plutonium. Another factor is cost, which is 1.5 times more than that of constructing a light-water reactor generating the same amount of electricity—670 000 kW.

NOV 22. Apple Computer Inc., Cupertino, Calif., and **Fujitsu Ltd.**, Tokyo, said they would join forces to produce multimedia software by exchanging program data in order to develop compatibility between Apple's Macintosh and Fujitsu's FM Towns computers. The companies said they would also encourage software companies to develop programs that would run on the machines of both companies.

NOV 23. California's **Sun Microsystems Inc.**, Mountain View, and **NeXT Computer Inc.**, Redwood City—former rivals—said they would work together to build an alternative to Microsoft Corp.'s planned Cairo object technology operating system. Sun will invest $10 million in NeXT in exchange for access to the company's object-oriented software, which makes it possible to quickly build modular applications. NeXT will also open up its proprietary operating system, NextStep, by licensing its so-called application environment to all comers at no charge.

NOV 24. Asea Brown Boveri Ltd., Zurich, Switzerland, said it had signed an agreement with China's Beijing Rectifier Plant to make digital converter equipment for electrical drives. The venture will be majority owned and managed by ABB.

NOV 24. Electronic Data Systems, General Motor Corp.'s subsidiary in Dallas, Texas, said it had won a $1.48 billion contract to run the computers for **Inland Revenue**, Britain's tax agency. Under the 10-year pact, 2000 Inland Revenue technicians will become EDS employees and manage the computers used to process UK tax returns and collect taxes. The deal was called the biggest "outsourcing" pact ever made in Europe.

NOV 24. Researchers at Sandia National Laboratories, Albuquerque, N.M., using an **Intel Corp.** Paragon supercomputer, said they had achieved a U.S. speed record of 102.5 gigaflops. The world record of 124 gigaflops was set in Japan on a Fujitsu Ltd. supercomputer.

NOV 24. NCR Corp., the computer unit of AT&T Co., said an early retirement program would be offered to 25 000 employees, or nearly half its workforce. The company expects about 7500 workers to accept the offer. The cuts are intended to reduce costs as the company moves to advanced microchip technology.

DEC 1. Intel Corp., Santa Clara, Calif., and **General Instrument Corp.**, Chicago, announced that they had jointly developed high-speed communications devices linking personal computers to cable-TV networks. Data is sent over cable lines 1000 times faster than over standard telephone lines. The companies plan to introduce their technology in several cable-TV trials early this year, including one by Viacom Cable in Castro Valley, Calif.

DEC 1. The **Semiconductor Industry Association**, San Jose, Calif., said Japan's **Sumitomo Chemical Corp.** had resumed making epoxy resins used to encase chips. The company's Niihama plant had been idled by an explosion on July 4, spurring a five-month panic among chip manufacturers that triggered price increases of 50 percent for certain key chips, such as dynamic RAMs.

Preview:
JAN 24–27. ComNet '94, to be held at the Washington, D.C., Convention Center, will exhibit networking products and applications and present a live demonstration of how local-, metropolitan-, and wide-area networks can work together. For information, call 800-225-4698 or 508-879-6700.

Sally Cahur

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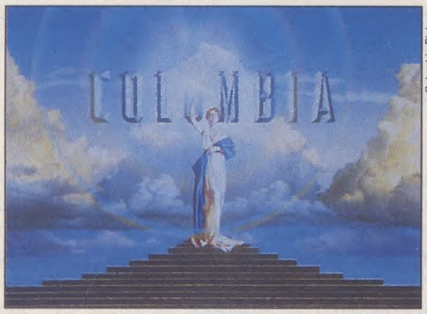

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Users want multimedia as vibrant as this logo newly animated by Kleiser-Walczak Construction Co. ***35***

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AT&T Bell Laboratories

At left, on a tour of Global Link, *AT&T's cable ship, is a Russian under contract to AT&T Bell Labs—Evgenyi Dianov, fiber optics department head at Moscow's Physics Institute. The others are Alice White, a Bell research department head; Leonard Becicka, the captain; and Jim Barrett, a vp at AT&T's Submarine Systems.* ***22***

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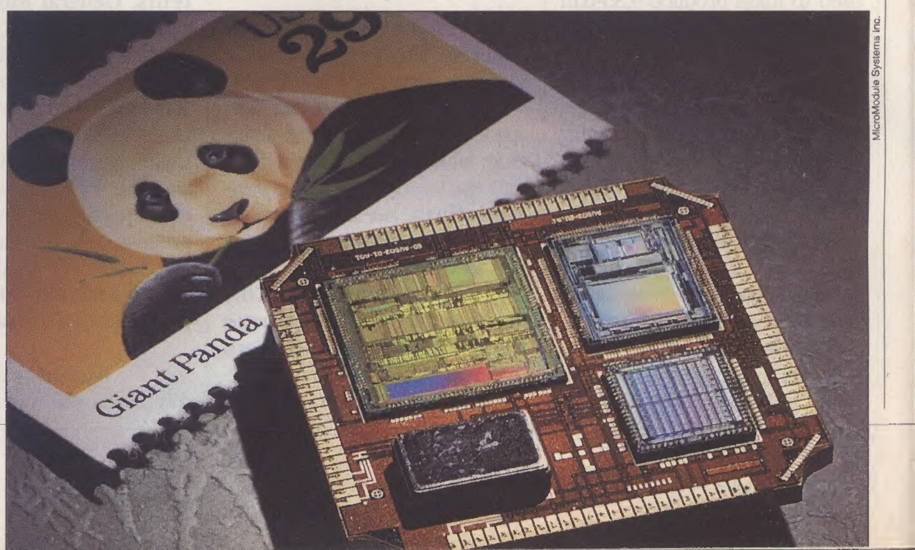

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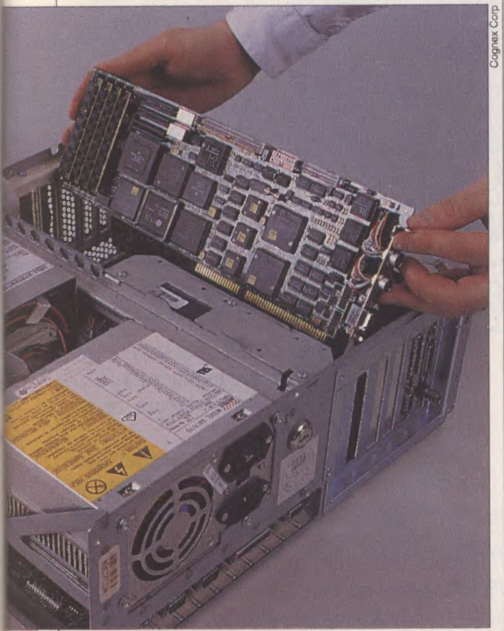

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Cover: The prototype single-stage-to-orbit DC-X made its maiden flight on Sept. 11, 1993, at the U.S. Army's White Sands, N.M., missile range. It is seen here in mid-ignition (at full ignition, the fuel mix burns blue-white). But final tests of the McDonnell Douglas one-third–scale model were not completed because funding was cut off. See p. 66.
Photo: U.S. Army

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Reflections

The disappearing space crunch

Several years ago I wrote an essay about the problems of managing space in engineering laboratories and offices—how there was a perpetual space crunch because engineers tended to accumulate and hide excess square footage.

That was then, but things have a way of changing. Now when I visit labs and offices, I see empty rooms and disused equipment everywhere. Why is this?

One theory is that the present surplus of space is really the visible manifestation of another trend: like there are getting to be too few people. Engineers are disappearing, and as in the behavior of semiconductors, they leave holes behind in the form of empty offices and labs.

In an equilibrium condition, these space holes are greatly attracted to incoming engineers, and a mating occurs that eliminates the hole along with the transient engineer, accompanied by a slight release of energy. In the present disequilibrium, however, there are too few new engineers to mate with the drifting office and lab holes. This results in a positively charged atmosphere.

As I walk down the empty corridors, I occasionally stagger and lose my footing in the near field of attraction from the empty labs and offices. I hear the groaning and feel the shifting of the building superstructure under the unbalanced gravitational forces emanating from the sides of the corridors.

Where have all the engineers gone? Alas, they have been "downsized." This inoffensive word in fact means that the company has fired a bunch of people. We speak of the "company" as downsizing in order not to imply that people are making these decisions.

Why does the company do this? Well, it looks around and sees that its competitors have downsized and so, to remain competitive, it too must downsize. Moreover, downsizing is fashionable, and proves how macho the management is. As a result of all the downsizing done by the companies in a given market, they remain relatively as competitive as they were before. The only difference is that society has a lot of surplus people to support. (There is obviously something more here that I fail to appreciate.)

I realize that downsizing is the popular explanation for the empty space, but I am prepared to advocate another theory. Before I explain my theory, though, let me tell of the incident that led to my inspiration.

Some years ago I was speaking to a group of younger engineers and, as older engineers are thoughtlessly prone to do, I began speaking of the "good old days." In those days, I recounted, we used to roll nickels down this very corridor. I waved vaguely at the seemingly endless passageway that disappeared off toward the horizon. We would listen to the hum as the nickel sped its way down the flooring, with ears keenly tuned to the clinking that would precede the nickel crashing and burning at the side of the corridor. Whoever got the longest run from his nickel was the winner of whatever was at stake.

Norm Bendell

The younger engineers looked at me blankly. "This is what you used to do?," they were saying to themselves. "This is how you get ahead in this company?" I sensed a failure in communication.

"Don't you people do anything crazy now?," I asked anxiously. "I mean...does anyone have any fun anymore?"

There was a long pause. Then one of the engineers cleared his throat hesitantly. "Well, now that you ask...," he started, and then proceeded to describe an incident of revenge that had been provoked by the arrogance of a newly promoted supervisor.

The new supervisor, as befitting his lofty rank, had moved into a large office, where he held audiences with his former friends, now his subordinates. After taking about as much of his loftiness as they could handle, the subordinates conceived a plan. Every night after he had left, they moved the partitioned walls of his office inward a few inches, giving him an ever so slightly smaller office each time.

At first the effect was not noticeable, but even after there had been a substantial reduction in his space, they heard no complaint. After all, what could he say? Imagine going to your supervisor with the complaint that your office was getting smaller! This stalemate continued until there wasn't enough room in the supervisor's office for his chair; only his desk fitted within the narrowed walls. Then, of course, the game was up, but what a run it had been, the young engineer bragged! "Of course we have fun," he said. "You just don't know about it."

Now what does this have to do with the empty offices we now encounter everywhere? There is a simple explanation. My theory is that *the buildings are getting bigger*. This is happening slowly at night when we are not looking. It happens at the time when the paper clips in our desks are mating. It is the time when old socks are leaving home and umbrellas are taking wing. It is the time when inanimate objects rebel against human control.

There is, of course, a scientific explanation for this phenomenon. It is a direct consequence of the big bang and the subsequent explosion of the universe. The red shift and Hubble's constant are involved, but that is getting too technical. The consequent expansion of buildings is difficult to measure because, diabolically, the measuring equipment is also getting larger. It is only we who are being left behind.

Tomorrow when you go to work, look carefully at your building. It may seem innocent enough, but examine it closely and see if you cannot discern a smirk of satisfaction on its edifice. It has grown a tiny bit while you slept. Today may be the day when someone looks at one of the labs and decides there is enough unused space to partition and create a new empty room. Think back and ask yourself where that empty space came from. Consider the theory of surreptitious, incremental growth. Makes sense, doesn't it?

Robert W. Lucky

The Delta Clipper Experimental DC-X.

THE NEXT BREAKTHROUGH IS YOURS.

Some people called McDonnell Douglas Aerospace's mission "unthinkable": develop a prototype reusable single-stage rocket vehicle in less than two years. And do it on a budget that was unthinkably tight.

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Forum

Flight observations

I found the Newslog item on guidance of U.S. civilian aircraft by Global Positioning System (GPS) satellites very interesting [November, p. 1]. As an engineer I worked with most major airlines, mainly Boeing and Douglas, helping to design panels for the 707 through the 747 and even the SST.

I recently crossed the Atlantic on a British Airways 747-400 aircraft. During the flight I was allowed to visit the cockpit and sat in between the pilot and co-pilot discussing operations. At the time we were at 37 000 feet.

I said to the captain I assumed they were using GPS. He said no, they did not feel that the satellites were stable or reliable enough and only used ground-based points. Apparently British Airways felt that GPS could drift or fail.

Depends on your point of view.

Gerald C. Ansell
Corvallis, Ore.

Solar power for cars

William C. Gallip's suggestion [October, p. 7] that electric vehicles be covered with solar cells to extend range and reduce use of utility electricity is qualitatively fine. Unfortunately, solar power is quantitatively impossible for anything except a mini-minicar (a microcar?). Solar energy is too diffuse.

The solar insolation outside the earth's atmosphere is 1 kilowatt per square meter (or square yard, for all practical purposes), yielding 24 kWh per day. Experience has shown that an electric vehicle converted from a conventional car usually requires a minimum of about 30 kWh stored in the battery.

Assuming that the surfaces of a car referred to by Gallip cover 5 ft by 10 ft, or 50 ft^2, this sounds good—about 5 m^2 or 120 kWh/day available from the photovoltaic cells. Charge the batteries in 6 hours! But wait: the sun shines, on the average, 12 hours per day at any given place. So the effective energy is reduced to 60 kWh. This still sounds good. But the atmosphere absorbs energy, the insolation at the earth's surface is a function of latitude, clouds block the sun, and so on. The Jet Propulsion Laboratory has given a rule of thumb of 2.4 kWh per day, per square meter. So, after a 10 percent conversion of efficiency is considered, $2.4 \times 5 \times 0.1 = 1.2$ kWh. Nice, but not for a car.

The Sunraycer photocell-energized racer, built by Paul MacCready and his associates for the 1989 Solar Energy race across Australia, was covered with photovoltaic cells, and traveled magnificently, with just about 1.5 kWh stored in its batteries. It was an experimental, ultralightweight vehicle built to prove principles. MacCready is the first to state that the principles do *not* include the possibility that solar-energized cars can be used at present to replace conventional vehicles.

If laws are changed allowing ultralightweight cars on roads and highways, and many other factors about the universe of our car-dependent socioeconomic structure are modified, then solar cars and solar parks for charging them may be possible.

Victor Wouk
New York City

Cellular safety debate

After reading all the comments about RF/VLF emission safety [October, p. 6], I should like to add two—rather basic, I think—observations.

I find little or no consideration in current publications of possible harmful effects on people of VLF or RF electromagnetic fields other than tissue warming or induced currents. It should be obvious that magnetic interaction with molecules in the body does happen. In the case of VLF emissions, a number of body functions are observed to cause small currents or magnetic fields with frequencies in the range of several 10 Hz—just think of nerve signals. Every designer of sensitive equipment would spend considerable effort in researching possible interference in this case, but biological electromagnetic compatibility (EMC) research seems to be rare.

The usual reference for pathological reactions seems to be cancer. The oversight here is that a number of factors, including electromagnetic fields, may affect a patient to lesser but still relevant degrees.

If I hit a person over the head with a small hammer (not too hard) every day, I would bet that his or her risk of developing cancer from this mistreatment would be quite small, and would therefore not show up in a statistical study. Still, the person would quite definitely be adversely affected by the blows!

A friend of mine, an acupuncture therapist, has observed that for a number of patients, progress in the treatment of chronic diseases will sometimes only be made after the patient's sleeping environment has been cleared of electrical equipment such as radios and televisions. His explanation is that the body needs phases of complete relaxation to regenerate its own immune system and that continued exposure to VLF fields will keep the system busy in "defense mode."

I would sincerely hope that researchers in this area develop a broader field of view for nonobvious interactions and a deeper sense of the effects of nonlinearity that can turn classical cause and effect thinking completely upside down at times. When talking about electronic devices, the researchers understand these concepts quite well. What they must learn is that humans are not electronic devices.

Peter G. Holzleitner
Vienna, Austria

Following up Fowler

As a retired engineer and manager who followed the same career path that Charles A. Fowler did (albeit not nearly so far), I believe his "DOs and DON'Ts for young EEs" [October, pp. 59–61] are excellent advice. I believe that this is particularly so with regard to the need for keeping in touch with the boss.

I must, however, take exception to his summary remark that "it is not the vice presidents, the managers,...the 'ilities' guys...who are asked to fix things..." With all due respect to us design engineers, over a 37-year career I saw many cases where the vice presidents and managers were able to provide the clout to "let" a problem be fixed when the design engineers had the solution but could not get it accepted.

Similarly with the "ilities," I have seen cases where component and process engineering came up with the alternate part, material, or process that saved the design engineers when they had boxed themselves into a corner with a design that did not quite work because of some temperature, producibility, or space problem.

Finally, it was the failure analysis people who often came through with the answer as to why some new hardware or software design package failed in system testing or after field deployment—leading the way to a solution.

The purpose in pointing this out is to try to prevent the stereotyped perception many older design engineers have that other groups contribute little or nothing to the overall engineering process from being passed on to yet another generation of young engineers.

Incidentally, Fowler's advice is as applicable to the other engineering disciplines as it is to young EEs.

William F. List
Linthicum, Md.

Fowler's article was insulting to many engineers and furthers the elitist attitude many designers already have. He calls quality, reliability, manufacturability, and so on the "fringes" of engineering, and implies that they are not a worthy career choice for a *real*

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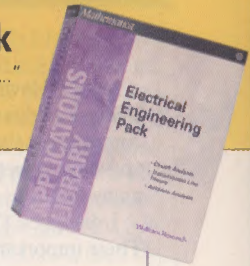

OTHER SYSTEMS CAN GET YOU ONLY SO FAR ...

Engineers and scientists who start with other technical software programs soon reach a point they can't get past. The project isn't finished, but the software is. What can they do then but buy and learn yet another program for the next leg of the project, or return to pencil and paper to finish it out.

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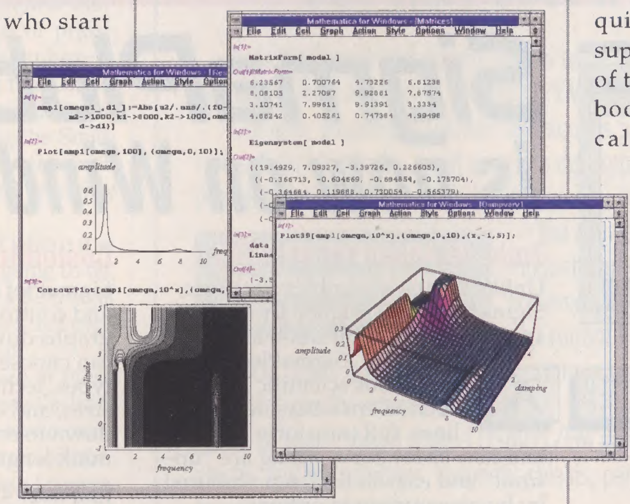

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Circle No. 9

Forum

engineer. Having worked in quality and reliability, in addition to design engineering, I can confirm that there are pros and cons to each, and such career decisions should be based on many factors.

I disagree that these areas are "fads." Their importance has become increasingly apparent as we have learned what is necessary to be competitive in a world marketplace. Unfortunately, Fowler's attitude is shared by many design engineers, which is why products that fail often or cannot be manufactured cost-effectively continue to get designed. My advice to young EEs is to learn as much as you can about these areas, and use them in whatever career path you choose. This will make you a much more valuable engineer.

Cindi Anderson
San Jose, Calif.

I tend to agree with Fowler's remarks about the "ilities" (a term I despise). The assurance technologies have much to recommend them. The young EE, however, is too naive to appreciate their worth in the beginning of a career.

Like Fowler, I have spent more than 40 years in my profession. The beginning years were devoted to understanding the field of design engineering, and I gained a modestly good reputation as a color TV design engineer and then as a frequency control "expert." It was not until 1960 that I became one of the fathers of the reliability department at Magnavox, assigned as a circuit reliability analysis leader. From then on, I stayed in R& M almost until the end of my career (I retired two years ago), although most of my work was in other areas, such as automatic testing.

The assurance technologies field has been good to me. I have never been unemployed, although some people I know have been, at one time or another. U.S. industry *still* has not learned the lessons taught by Deming, Juran, Feigenbaum, and the rest. We are still struggling, in this country, to catch up to the Japanese, Germans, Koreans, and others, in the production of quality products. Read for "quality," however, the rest of the assurance technologies, which attempt to provide the customer with a good, working product that will withstand the test of time and use—what reliability engineers refer to as "failure-free" operation, a dream that is still in formation.

I do not know what Fowler really meant by the "fringes of engineering," but it almost sounds pejorative. I hope it was not meant that way, because it would indicate Fowler's bias and misunderstanding of our technical field.

After all, there are some 3000 IEEE members who belong to the Reliability Society and several more thousands in ASQC and other organizations. Our annual symposium (RAMS) is considered one of the best organized and run in the nation. In January 1994, in Anaheim, Calif., we will be presenting 20 tutorial sessions. History shows that at least 50 people will attend each tutorial. Something good must be going on. Even if you consider yourself a design engineer, it might be useful to attend some of the tutorials, which will teach you more about how things can fail, improving your skills in developing things that work.

Alan O. Plait
Springfield, Va.

On Spectral Lines

In "Of wishes, hopes, and schemes" [October, p. 21], Murray Slovick repeats a suggestion that reports of a successful Strategic Defense Initiative (SDI) test may have been an "elaborate fraud," and he frets that some engineers may have behaved unethically.

Journalists would do well to recognize that the threat of SDI, whether real or fabricated, was a major factor in the collapse of the Soviet Union and the end of the arms race. If the test was covertly rigged, the engineers involved participated in a legitimate strategic deception in defense of this nation. Knowledge of such deception, if it occurred, would necessarily be withheld from journalists and

politicians. Does Slovick consider it unethical for General Schwarzkopf to have deceived Iraqi forces into believing that the thrust into Kuwait would come by amphibious landing?

Difficult as it may be for a journalist, the editor of *IEEE Spectrum* must learn to distinguish between fraud in pursuit of unfair commercial advantage on the one hand and strategy in furtherance of national security on the other. The former is unethical; the latter is not.

Marvin R. Heembrock
Penn Valley, Calif.

What is the problem?

Robert Lucky's essay, "Technology isn't the problem" [November, p. 14], was interesting and well written, but it failed to mention what should have been its most important point: technology is a much easier enterprise than business, economics, advertising, politics, and the law. Engineering and science—which together embrace what most of us mean by "technology"—consist in essence of discerning and exploiting the laws of nature. That is a comparatively easy business, given nature's regularity and its obedience to knowable (and largely known) laws.

The other fields, by contrast, consist in essence of attempting to manipulate and exploit human nature, but with almost no knowledge of how the human mind works. Other than a few purely qualitative principles—such as that humans are shortsighted, greedy, afraid of change, power-hungry, manipulative, and desirous of praise—what does a politician or marketer have to guide his or her work? Nothing that comes even close to the power and reliability of tools like finite-element analysis, the Smith chart, or the Bode plot, not to mention such overarching concepts as general relativity and quantum electrodynamics.

We engineers work in a field where it is possible to know what you are going to do, and we do. The others work in a field so ill defined and riddled with quagmires that even characterizing it has me stumped.

One very serious consequence of these facts is that technologists are giving the business and political leaders of the world capabilities that those lay leaders are incompetent to manage. The most obvious, of course, is the atomic bomb. Look at how many hundreds of billions of dollars have been wasted in developing those weapons and then defending against them. Look and either weep or laugh at the absolutely insane behavior of our entire species.

Today, the big danger is automation. We are fast figuring out how to produce the goods and services we need without a human labor force. But we have not figured out a better way to distribute the wealth that will be produced other than by rewarding work. This can lead nowhere good.

Might it not be a good idea to slow down the one until the other catches up?

Name withheld on request
New York City

Corrections

On p. 42 of the September issue, under Acknowledgments, Thomas Stepien should have been listed as a member of the team.

On p. 1 of the November issue, in the first listing for Sept. 29, the fuel efficiency should have been "80 miles per gallon (3 liters per 100 kilometers)."—*Ed.*

Readers are invited to comment in this department on material previously published in IEEE Spectrum; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contact: Forum, IEEE Spectrum, 345 E. 47th St., New York, NY 10017, U.S.A.; fax, 212-705-7453. The e-mail (Internet) address is n.hantman@ieee.org. The computer bulletin board number is 212-705-7308; the password is SPECTRUM. For more information, call 212-705-7305 and ask for the Author's Guide.

Books

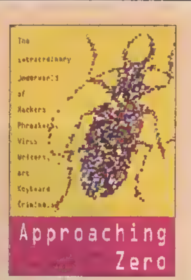
Keyboard crime or pubescent hubris?

Mike Godwin

Computer journalists typically portray so-called computer "hackers" in one of two ways. The first involves analyzing their activities, both legal and illegal, as part of a cultural movement or the outcome of a clash of subcultures. Examples of this approach include Steven Levy's *Hackers* (published by Anchor Press/Doubleday in 1984) and Bruce Sterling's *The Hacker Crackdown* (Bantam, 1992). With this book, however, Paul Mungo and Bryan Clough take the other approach: treating hackers essentially as common criminals.

The problem with these approaches is that each tends to miss an important dimension of the hacker phenomenon. Dealing with hackers and "phreakers" as members of a distinct culture or subculture tends to obscure the fact that they are also members of the society whose rules they are knowingly violating. And while some kinds of hacking (for example, attempts to thwart security systems and explore the capabilities of large computers) are driven by intellectual curiosity, other kinds (toll fraud, credit card fraud, computer vandalism, and most releases of computer viruses) are essentially criminal and cannot be dismissed so lightly.

Approaching Zero: The Extraordinary Underworld of Hackers, Phreakers, Virus Writers, and Keyboard Criminals.
Mungo, Paul, and Clough, Bryan, Random House, New York, 1993, 247 pages, $22.00.



On the flip side, the assumption that hackers and virus-writers are just criminals with new tools—an assumption explicit in this book's subtitle—has its own hazards. For one thing, it invites lawmakers and enforcement officials to treat hackers as the digital equivalents of burglars and thieves, when all too often their motives are far more innocuous, and the harm they cause far less damaging.

Another problem with this mind-set is that it offers no insights into run-of-the-mill computer malfeasance. The vast majority of computer intruders are teenagers and post-adolescent males who seem more interested in ferreting out secrets (and becoming famous for their ability to do so) than in stealing or doing harm to man or machine. Many of them dream of becoming computer security professionals or offering their services to their countries' intelligence and law enforcement agencies. Still others justify their actions as expanding knowledge about computers, exposing the weaknesses of critical systems, or empowering individuals to control the technology that is increasingly being used to control them. Trying to understand their motives in terms of traditional criminality is an enterprise doomed to frustration.

Do these hackers' sometimes enthusiastic, sometimes anguished justifications of computer hacking represent *post-hoc* rationalizations of illegal acts? Of course, in some cases. But they also may point to some essential truth about the motivations for hacking. In her insightful book *The Second Self: Computers and the Human Spirit* (Harvard Uni-

versity Press, 1984), Sherry Turkle argues that computers are different from other tools because they lend themselves more easily to projections of our normal human needs and concerns. Adolescents, she writes, may find their computer skills to be both a refuge and a testing ground for self-definition.

The fact that hackers don't always easily fit the criminal model dogs *Approaching Zero* from start to finish, with many facts and stories undermining the book's claim to be a sensational account of an "underworld" full of "keyboard criminals." For example, the authors detail how the computer security industry, with the willing assistance of the trade press, actually did much to create the underworld of virus writers by publicizing virus "epidemics" long before any had occurred. And the authors make no attempt to conceal the fact that the average would-be hacker is a nerdy teenager with a penchant for dangerous-sounding "handles" (a sort of *nom de* hack). This is not the stuff computer crime waves are made of.

The authors also explore more familiar ground, such as the history of phone "phreaking" (evading long-distance charges, for the most part) and its growth into a subculture of teenage hackers with bulletin-board systems, electronic newsletters, and anarchic attitudes. And it is in this familiar territory that the authors' haste and the book's consequent weaknesses become apparent. Since the material was largely pulled from secondary sources, mistakes in the original newspaper and magazine accounts are often reproduced.

These errors range from the small (Southwestern Bell security expert Reed Newlin becomes Reed Nolan) to the unconscionable. In describing the U.S. Secret Service's ill-considered raid on Steve Jackson Games, for example, the authors write that "the company specialized in publishing computer games." In fact, the company has never published a computer game; it produces role-playing games based on rulebooks and special dice, not computers and diskettes. So when the Secret Service decided on the basis of scanty and misunderstood evidence to seize the company's bulletin-board system and manuscripts, it was shutting down a publisher of materials protected by the First Amendment, as evidenced by the company's recent successful lawsuit against the U.S. government.

The authors also assert that the raid was part of the Secret Service's now infamous Operation Sundevil, an antifraud operation. It has long been established that Sundevil, while similarly ill-conceived, was wholly separate from the Chicago-based investigation that resulted in the illegal search and seizure at Jackson's game company. These facts are documented in Sterling's book and elsewhere, but the authors seem not to have gone beyond the earliest newspaper clippings.

The book does shine, however, in its discussion of microcomputer viruses, particularly in the chapter on the Bulgarian virus writers, whose internationally effective labors stand as an apparent testament to the fact that there's nothing else to do on a Saturday night in Sofia. It is no coincidence that these parts of the book are based on the authors' own original research; Mungo, a magazine journalist, and Clough, a British computer security expert, have each written about virus writers, and readers will discover facts about the explosion of virus writing in the late '80s and early '90s that do not appear in other treatments of the phenomenon.

For these chapters alone, if not for its general merit, *Approaching Zero* deserves a place on the bookshelves of those interested in computer hacking, computer crime, and the legal and social issues raised by both.

Mike Godwin is on-line counsel at the Electronic Frontier Foundation in Washington, D.C., where he advises users of electronic networks about their legal rights and responsibilities, conducts seminars, and instructs criminal lawyers and law enforcement personnel about computer civil liberties. He has written many articles on topics such as electronic searches and seizures, the First Amendment and electronic publications, and the application of international law to computer communications.

Calendar

Meetings, Conferences, and Conventions

JANUARY

International Conference on Wafer Scale Integration—ICWSI (C, CHMT); Jan. 19–21; Fairmont Hotel, San Francisco; Stuart Tewksbury, Department of Electrical and Computer Engineering, Engineering Science Building 827, West Virginia University, Morgantown, WV 26506; 304-293-6371; fax, 304-293-5024.

Annual Reliability and Maintainability Symposium—RAMS (R); Jan. 25–27; Anaheim Marriott Hotel, Anaheim, Calif.; V. R. Monshaw, Consulting Services, 1768 Lark Lane, Cherry Hill, NJ 08003; 609-428-2342.

Power Engineering Society Winter Meeting (PE); Jan. 30–Feb. 3; New York Hilton and Towers, New York City; Frank E. Schink, 14 Middlebury Lane, Cranford, NJ 07016-1622; 908-276-8847.

FEBRUARY

10th Semiconductor Thermal Measurement and Management Symposium—Semi-Therm (CHMT); Feb. 1–3; Red Lion Hotel, San Jose, Calif.; Bonnie Crystall, C/S Communications Inc., Box 23899, Tempe, AZ 85285; 602-625-0700.

15th Aerospace Applications Conference (AES); Feb. 5–12; Mountain Haus, Vail, Colo.; Chuck Zamites, 1719 Morgan Lane, Redondo Beach, CA 90278.

Digital Video Compression on Personal Computers: Algorithms and Technologies Conference (C); Feb. 6–10; San Jose Convention Center, California; Jane Lybecker, SPIE, Box 10, Bellingham, WA 98227; 206-676-3290; e-mail, janel@mom.spie.org; or Arturo A. Rodriguez, Kaleida Laboratories; e-mail, aar@kaleida.com.

High-Speed Networking and Multimedia Computing Conference (C); Feb. 6–10; San Jose Convention Center, California; Jane Lybecker, SPIE, Box 10, Bellingham, WA 98227–0010; 206-676-3290; e-mail, janel@mom.spie.org; or Arturo A. Rodriguez, Kaleida Labs; e-mail, aar@kaleida.com.

Basque International Workshop on Information Technology (C); Feb. 7–9; Hotel Athlanthal, Biarritz, France; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013; fax, 202-728-0884.

Second CAD-Based Vision Workshop (C); Feb. 8–10; Seven Springs Mountain Resort, Champion, Pa.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013; fax, 202-728-0884.

Applied Power Electronics Conference and Exposition—APEC '94 (IA, PEL); Feb. 13–17; Walt Disney World Resort, Orlando, Fla.; Pamela Wagner, Courtesy Associates, 655 15th St., S.W., Suite 300, Washington, DC 20005; 202-639-4990; fax, 202-347-8109.

Network Operations and Management Symposium (COM); Feb. 14–18; Hyatt Orlando Hotel, Kissimmee, Fla.; Jill Pancio, Pacific Bell, Room 100, 7620 Convoy Court, San Diego, CA 92111; 619-268-6135; fax, 619-292-1509.

10th International Conference on Data Engineering (C); Feb. 14–18; Doubletree Hotel, Houston, Texas; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013; fax, 202-728-0884.

(Continued on p. 15)

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For additional information on hotels, conference centers, and travel services, see the Reader Service Card.

Recent books

Digital Image Processing. *Teuber, Jan*, Prentice Hall, Englewood Cliffs, N.J., 1993, 263 pp., $40.

Composite Materials in Maritime Structures: Fundamental Aspects, Vol. 1. Eds. *Shenoi, R. A.*, and *Wellicome, J.F.*, Cambridge University Press, New York, 1993, 351 pp., $69.95.

Composite Materials in Maritime Structures: Practical Considerations, Vol. 2. Eds. *Shenoi, R.A.*, and *Wellicome, J. F.*, Cambridge University Press, New York, 1993, 306 pp., $69.95.

Advanced Topics in Materials Science and Engineering. Eds. *Moran-Lopez, J.L.*, and *Sanchez, J.M.*, Plenum Publishing, New York, 1993, 356 pp., $95.

The AMA Handbook of Project Management. Ed. *Dinsmore, Paul C.*, Amacom, New York, 1993, 489 pp., $85.

VM/CMS: Concepts and Facilities. *Savit, Jeffrey*, McGraw-Hill, New York, 1993, 461 pp., $45.

The ISO 9000 Book: A Global Competitor's Guide to Compliance and Certification. *Rabbitt, John T.*, and *Bergh, Peter A.*, Amacom, New York, 1993, 176 pp., $26.95.

Lee de Forest and the Fatherhood of Radio. *Hijiya, James A.*, Lehigh University Press, Cranbury, N.J., 1992, 177 pp., $32.50.

Learning to Manage Technical Professionals. *Stein, Richard J.*, Addison-Wesley, Reading, Mass., 1993, 208 pp., $25.95.

Introduction to Artificial Neural Systems. *Zurada, Jacek M.*, West Publishing Co., St. Paul, Minn., 1992, 785 pp., $51.75.

Assessing the Base Force: How Much is Too Much. *Kaufmann, William W.*, Brookings Books, Washington, D.C., 1992, 97 pp., $9.95.

Performance Contracting for Energy and Environmental Systems. *Hansen, Shirley J.*, Prentice Hall, Englewood Cliffs, N.J., 1993, 317 pp., $69.

Silicon Mirage: The Art and Science of Virtual Reality. *Aukstakalnis, Steve*, and *Blatner, David*, Peachpit Press, Berkeley, Calif., 1992, 300 pp., $15.

The Corporate Cabling Guide. *McElroy, Mark W.*, Artech House, Norwood, Mass., 1993, 111 pp., $60.

The Computer Professional's Guide to Effective Communication. *Simon, Alan R.*, and *Simon, Jordan S.*, McGraw-Hill, New York, 1993, 275 pp., $29.95 (hardcover), $19.95 (paperback).

Digital Design Fundamentals. *Breeding, Kenneth J.*, Prentice Hall, Englewood Cliffs, N.J., 1992, 446 pp., $60.

Serial Communications: AC++ Developer's Guide. *Nelson, Mark*, M&T Books, San Mateo, Calif., 1992, 662 pp., $44.95.

Computer Aided Logical Design with Emphasis on VLSI, 4th edition. *Hill, Frederick J.*, and *Peterson, Gerald R.*, John Wiley & Sons, New York, 1993, 534 pp., $75.95.

Guide to the National Electrical Code, 1993 edition. *Harman, Thomas L.*, and *Allen, Charles E.*, Prentice Hall, Englewood Cliffs, N.J., 1993, 399 pp., $44.

Designing, Writing, and Producing Computer Documentation. *Denton, Lynn*, and *Kelly, Jody*, McGraw-Hill, New York, 1993, 258 pp., $39.95 (hardcover), $24.95 (paperback).

(Continued on p. 14FE)

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Recent books

(Continued from p. 14BE)

Intelligent Sensor Technology. *Ohba, Ryoji*, John Wiley & Sons, New York, 1992, 167 pp., $49.95.

Antenna Engineering Handbook, 3rd edition. *Johnson, Richard C.*, McGraw-Hill, New York, 1993, 1520 pp., $119.50.

Innovative Energy Design For The 90's. *Meckler, Milton*, Fairmont Press, Lilburn, Ga., 1993, 403 pp., $64.

Software Process Quality. *Yeh, Hsiang-Tao*, McGraw-Hill, New York, 1993, 200 pp., $40.

Developing C++ Software, 2nd edition. *Winder, R.*, John Wiley & Sons, New York, 1993, 494 pp., $39.95.

Essays on Object-Oriented Software Engineering, Vol. I. *Berard, Edward V.*, Prentice Hall, Englewood Cliffs, N.J., 1993, 352 pp., $35.

IBM RISC System/6000: A Business Perspective, 3rd edition. *Hoskins, Jim*, John Wiley & Sons, New York, 1993, 346 pp., $26.95.

Science with a Smile. *Weber, Robert L.*, Institute of Physics Publishing, Philadelphia, Pa., 1992, 452 pp., $39.

VSAM Architecture, Theory and Applications. *Brumbaugh, Larry J.*, McGraw-Hill, New York, 1993, 396 pp., $44.95.

The Anatomy of Programming Languages. *Fischer, Alice E.*, and *Grodzinsky, Frances S.*, Prentice Hall, Englewood Cliffs, N.J., 1993, 557 pp., $52.

Operational Amplifiers: Integrated and Hybrid Circuits. *Rutkowski, George B.*, John Wiley & Sons, New York, 1993, 357 pp., $69.95.

Concurrent Aggregates. *Chien, Andrew A.*, MIT Press, Cambridge, Mass., 1993, 194 pp., $30.

Physically-Based Modeling for Computer Graphics: A Structured Approach. *Barzel, Ronen*, Academic Press, San Diego, Calif., 1992, 334 pp., $39.95.

VHDL Programming with Advanced Topics. *Baker, Louis*, John Wiley & Sons, New York, 1993, 365 pp., $39.95.

Phase-Locked Loops: Theory, Oesign and Applications, 2nd edition. *Best, Roland E.*, McGraw-Hill, New York, 1993, 374 pp., $50.

Heisenberg's War. *Powers, Thomas*, Alfred A. Knopf, New York, 1993, 610 pp., $27.50.

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The ILS Manager's LSA Toolkit: Availability Engineering. *Biedenbender, Dick, et al.*, McGraw-Hill, New York, 1993, 574 pp., $57.

Sharks Have No Bones: 1001 Things Everyone Should Know About Science. *Trefil, James*, Simon & Schuster, New York, 1993, 305 pp., $12.

Telecommunication Transmission Systems: Microwave, Fiber Optic, Mobile Cellular Radio, Data, and Digital Multiplexing. *Winch, Robert G.*, McGraw-Hill, New York, 1993, 540 pp., $70.

Globalization, Technology, and Competition: The Fusion of Computers and Telecommunications in the 1990s. Eds. *Bradley, Stephen P., et al.*, Harvard Business School Press, Boston, 1993, 384 pp., $34.95.

Atmospheric Remote Sensing by Microwave Radiometry. *Janssen, Michael*, John Wiley & Sons, New York, 1993, 572 pp., $95.

Microwave Circuit Theory and Foundations of Microwave Metrology. *Engen, Glenn F.*, Peter Peregrinus/IEE, Piscataway, N.J., 1992, 240 pp., $49.

Handbook of Transformer Design & Applications, 2nd edition. *Flanagan, W.*, McGraw-Hill, New York, 1993, 300 pp., $59.50.

A Guide to Usability: Human Factors in Computing. *Preece, Jenny*, Addison-Wesley, Reading, Mass., 1993, 144 pp., $26.95.

The Effective Supervisor's Handbook, 2nd edition. *Imundo, Louis V.*, Amacom, New York, 1993, 212 pp., $16.95.

Internet Primer for Information Professionals. *Lane, E.*, and *Summerhill, C.*, Meckler, Westport, Conn., 1993, 200 pp., $37.50.

Data Communications Principles. *Gitlin, Richard D., et al.*, Plenum Publishing, New York, 1992, 733 pp., $95.

Digital Filter Designer's Handbook: Featuring C Routines. *Rorabaugh, C. Britton*, McGraw-Hill, New York, 1993, 332 pp., $49.95.

The Virtual Library: Visions and Realities. *Saunders, Laverna*, Meckler, Westport, Conn., 1993, 200 pp., $37.50.

Computer-Aided Analysis and Design of Switch-Mode Power Supplies. *Lee, Yim-Shu*, Marcel Dekker, New York, 1993, 648 pp., $125.

Microcontroller Technology, The 68HC11. *Spasov, Peter*, Regents/Prentice Hall, Englewood Cliffs, N.J., 1993, 622 pp., $61.33.

Japanese/English, English/Japanese: Glossary of Scientific & Technical Terms. *Tung, Louise Watanabe*, John Wiley & Sons, New York, 1993, 1146 pp., $79.95.

Electrical Sensors and Transducers. *Carstens, James R.*, Regents/Prentice Hall, Englewood Cliffs, N.J., 1993, 498 pp., $49.

Telecommunications Factbook. *Pecar, Joseph A., et al.*, McGraw-Hill, New York, 1993, 373 pp., $29.95.

Process Control Instrumentation Technology, 4th edition. *Johnson, Curtis*, Regents/Prentice Hall, Englewood Cliffs, N.J., 1993, 592 pp., $60.

VHF and UHF Antennas. *Burberry, R.A.*, Peter Peregrinus/IEE, Piscataway, N.J., 1992, 301 pp., $95.

Microsoft Windows 3.1 Developer's Work-

Recent books

shop. *Butler, John, et al.*, Microsoft Press, Redmond, Wash., 1993, 336 pp., $34.95.

The 80386DX Microprocessor: Hardware, Software, & Interfacing. *Triebel, Walter A.*, Prentice Hall, Englewood Cliffs, N.J., 1992, 523 pp., $62.

Engineering Applications of Correlation and Spectral Analysis, 2nd edition. *Bendat, Julius S.*, and *Piersol, Allan G.*, John Wiley & Sons, New York, 1993, 458 pp., $64.95.

Microsoft Visual C++ Run-Time Library Reference, Covers Version 1 of the Standard and Professional Editions. *Microsoft Corp.*, Microsoft Press, Redmond, Wash., 1993, 704 pp., $35.

Vortex Dynamics: Cambridge Monographs on Mechanics and Applied Mathematics. *Saffman, P.G.*, Cambridge University Press, New York, 1992, 311 pp., $69.95.

Fundamentals of Programmable Logic Controllers, Sensors, & Communications. *Stenerson, Jon*, Regents/Prentice Hall, Englewood Cliffs , N.J., 1993, 272 pp., $33.33.

Very Small Aperture Terminals (VSATs) . Ed. *Everett, John*, Peter Peregrinus/IEE, Piscataway, N.J., 1992, 543 pp., $119.

Fundamentals of Fibre Optics in Telecommunication and Sensor Systems. Ed. *Pal, Bishnu P.*, John Wiley & Sons, New York, 1992, 778 pp., $39.95.

Building a Better Mouse Trap: A Programmer's Guide to the Mouse. *Donovan, Jeffrey S.*, Osborne/McGraw-Hill, New York, 1993, 525 pp., $39.95.

Assembly Language Tutor for IBM PC & Compatibles. *Haskell, R.E.*, Regents/Prentice Hall, Englewood Cliffs, N.J., 1993, 464 pp., $40.

Word 5.1 Companion. *Cobb, Gena B., et al.*, Microsoft Press, Redmond, Wash., 1993, 720 pp., $29.95.

Electrostatic Discharge in Electronics. *Greason, William D.*, John Wiley & Sons, New York, 1992, 246 pp., $85.

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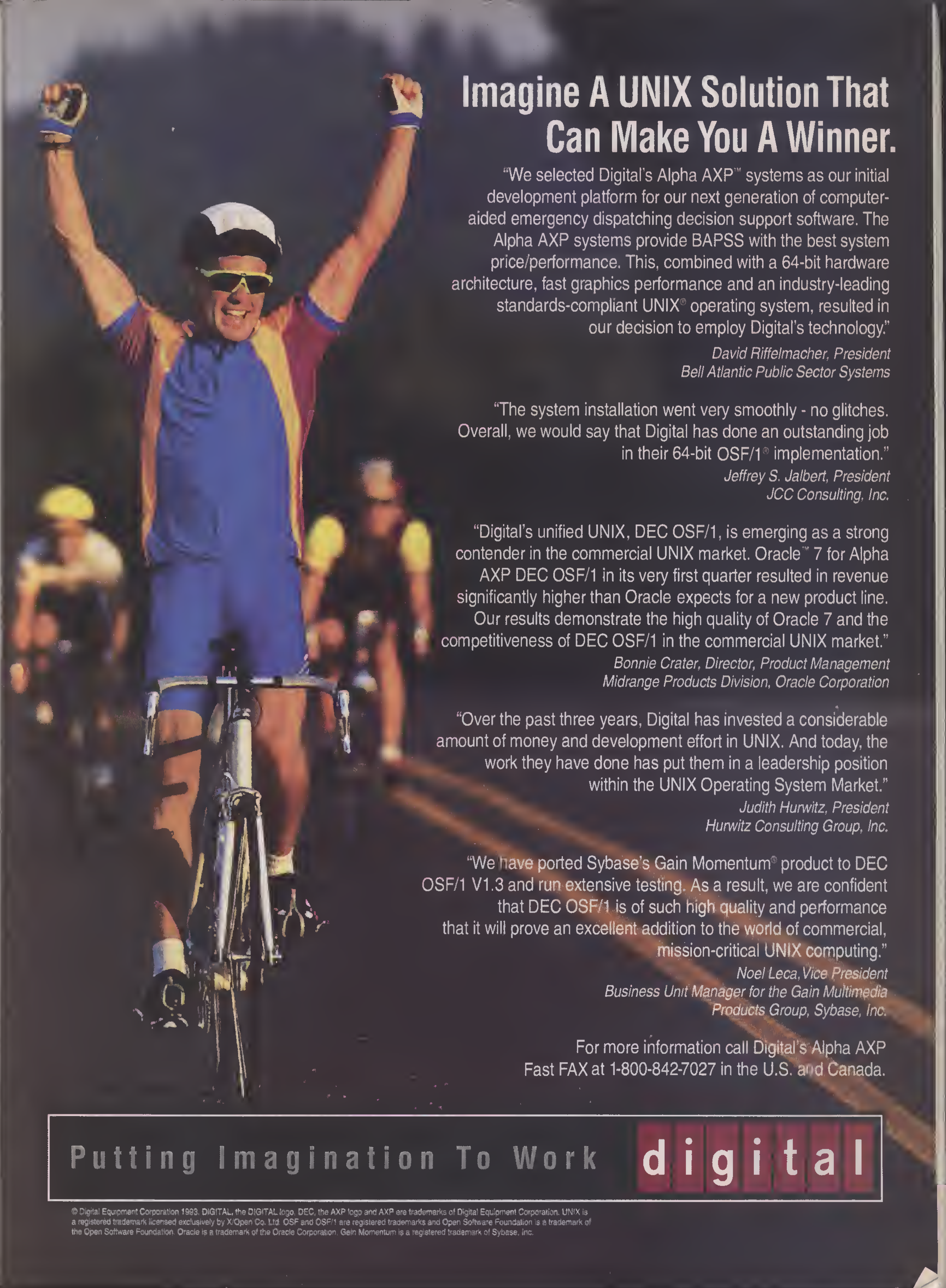

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Recent books

New York, 1993, 442 pp., $69.95.

Narrowband Land-Mobile Radio Networks. *Linnartz, Jean-Paul*, Artech House, Norwood, Mass., 1993, 345 pp., $88.

Introduction to Electric Circuits and Machines. *Simpson, Colin D.*, Prentice Hall, Englewood Cliffs, N.J., 1992, 812 pp., $59.33.

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Equations of Eternity: Speculations on Consciousness, Meaning, and the Mathematical Rules that Orchestrate the Cosmos. *Darling, David*, Hyperion, New York, 1993, 181 pp., $19.95.

Electronics Math, 4th edition. *Deem, Bill*, Regents/Prentice Hall, Englewood Cliffs, N.J., 1993, 729 pp., $52.

Practical Electrical Wiring: Residential, Farm, and Industrial, 16th edition. *Richter, Herbert P.*, and *Schwan, W. Creighton*, McGraw-Hill, New York, 1993, 643 pp., $35.

Electronic Warfare Receiving Systems. *Vaccaro, Dennis D.*, Artech House, Norwood, Mass., 1993, 319 pp., $88.

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The REDO Compendium: Reverse Engineering for Software Maintenance. Ed. *van Zuylen, H.J.*, John Wiley & Sons, New York, 1993, 405 pp., $195.

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Linear System Theory. *Rugh, Wilson J.*, Prentice Hall, Englewood Cliffs, N.J., 1993, 356 pp., $56.

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The 8051 Microcontroller: Hardware, Software and Interfacing. *Stewart, James W.*, Regents/Prentice Hall, Englewood Cliffs, N.J., 1993, 273 pp., $38.67.

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Introduction to Electronic Document Management Systems. *Green, William B.*, Academic Press, New York, 1993, 250 pp., $44.95.

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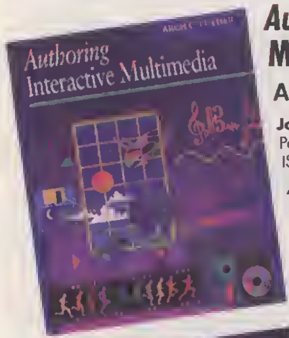

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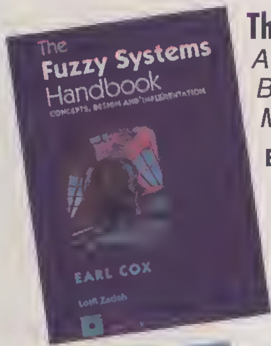

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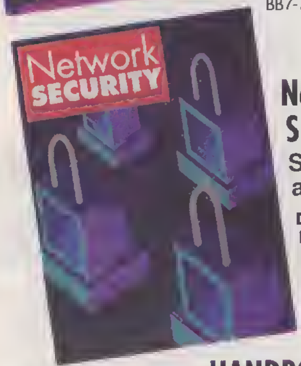

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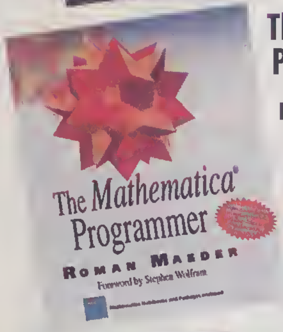

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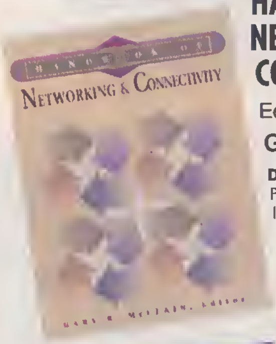

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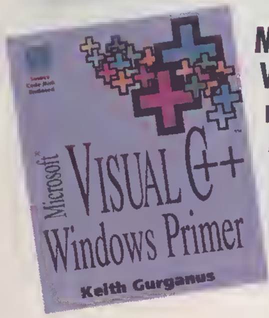

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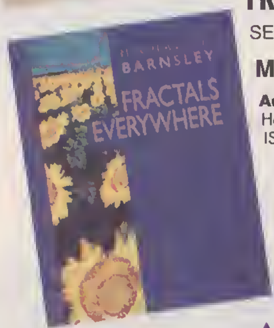

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AP PROFESSIONAL

Circle No. 27

Washington watch

And still some budgets grow

Despite loud calls for austerity, Congress backed much of the 1994 research program requested by the Clinton administration before members broke for the winter recess in November.

The National Science Foundation will get US $3.0 billion, up 10.7 percent from 1993; funding for the National Institute of Standards and Technology is up 35 percent to $520 million; and the National Oceanic and Atmospheric Administration's budget rose 11.9 percent to $226 million.

The National Aeronautics and Space Administration received $9.2 billion, a gain of 5 percent, and staved off efforts to kill the space station. That will be funded at nearly $2 billion.

The Department of Energy was not so lucky with the superconducting supercollider, which was eliminated by Congress despite the Administration's request for $640 million to continue the project. Congress approved other big DOE increases, however, notably in the areas of environment and renewable energy.

R&D in the Department of Defense fell 9 percent to $35.2 billion in fiscal year 1994 from $38.2 billion in fiscal 1993.

Clean manufacturing initiative funded

The Pentagon's Advanced Research Projects Agency (ARPA) received $20 million from Congress to embark on an environmentally conscious electronic systems manufacturing initiative. The program was spurred by industry—notably the Microelectronics and Computer Technology Corp. (MCC), Austin, Texas—and by the IEEE and other professional associations. Government grants will be competitively bid and cost shared.

The IEEE, MCC, Sematech, AT&T, and DuPont, among others, have also applied for a large grant in this area from ARPA's Technology Reinvestment Project.

One-stop guide to NIST research

Wending one's way through the Federal bureaucracy can be daunting: large firms have entire offices devoted to facilitating the task. With the help of a new "one-step" guide, it should now be easier to make sense of some 250 research programs under way at the growing National Institute of Standards and Technology (NIST). The 116-page guide includes sections on the Advanced Technology Program and Manufacturing Extension Partnerships.

Free copies are available to anyone sending a self-addressed label to NIST Public Affairs, A903 Administration Building, NIST, Gaithersburg, MD 20899-0001; fax, 301-926-1630; e-mail, telnet gopher.nist.gov (or use gopherserver.nist.gov with port 70).

IEEE-USA efforts in full swing

IEEE–United States Activities (IEEE-USA) has been making headway on the information superhighway, pensions, and patents. The U.S. Department of Commerce has asked the technology policy committee of IEEE-USA for nominations to fill two of the 15 slots for an advisory panel on the National Information Infrastructure, the emerging multi-

(Continued on p. 90F)

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Calendar

(Continued from p. 14)

International Solid-State Circuits Conference—ISSCC '94 (SSC, SF Section, et al.); Feb. 16–18; San Francisco Marriott, San Francisco; Diane S. Suiters, Courtesy Associates Inc., 655 15th St., N.W., Suite 300, Washington, DC 20005; 202-639-4255; fax, 202-347-6109.

Conference on Optical Fiber Communication—OFC '94 (COM, LEO); Feb. 20–25; San Jose Convention Center, San Jose, Calif.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331; 908-562-3893; fax, 908-562-1571.

Non-Volatile Semiconductor Memory Workshop (ED); Feb. 21–23; Hyatt Regency Hotel, Monterey, Calif.; Gregory E. Atwood, Intel Corp., 2220 Mission College Blvd., MS RNB3-01, Santa Clara, CA 95052; 408-765-9733; fax, 408-765-9206.

Symposium on Intelligent Systems In Communications and Power (COM, PEL); Feb. 21–23; Mayaguez Hilton, Mayaguez, P.R.; Hamed Parsiani, Technical Program Chairman, Department of Electrical and Computer Engineering, University of Puerto Rico, Mayaguez, PR 00681-5000; 809-832-4040, ext. 3653; fax, 809-831-7564.

MARCH

Columbia Basin Technical Conference and Trade Show (Richland Section); March 7–8; Red Lion Inn, Pasco, Wash.; A. Wayne Akerson, General Chairman, Box 1075, Richland, WA 88352; 509-373-1939; fax, 509-373-4362.

Symposium on Computer-Aided Control Systems Design—CSD (CS); March 7–9; Tucson Convention Center, Tucson, Ariz.; Paul Baltes, Engineering Professional Development, Box 9, Harvill Building, University of Arizona, Tucson, AZ 85721; 602-621-5104; fax, 602-621-1443.

Multi-chip Module Conference (ED); March 15–18; The Cocoanut Grove, Santa Cruz, Calif.; David P. LaPotin, IBM Thomas J. Watson Research Center, Box 218, Yorktown Heights, NY 10598; 914-945-2586; fax, 914-945-4469.

Networks for Personal Communications—NPC '94 (NJ Coast); March 16–18; Ocean Place Hilton, Long Branch, N.J.; Vijay K. Varma, Bellcore, 3X-325, 331 Newman Springs Rd., Red Bank, NJ 07701-7040; 908-758-2811; fax, 908-758-4371.

20th Northeast Bioengineering Conference (EMB); March 17–18; Western New England College, Springfield, Mass.; James V. Masi, Department of Electrical Engineering, Western New England College, Springfield, MA 01119; 413-782-1344; fax, 413-782-1746.

International Conference on Expert Systems for Development (C); March 18–21; Asian Institute of Technology, Bangkok, Thailand; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013; fax, 202-728-0884.

International Conference on Microelectronic Test Structures (ED); March 22–24; Catamaran Resort Hotel, San Diego, Calif.; Sandra Grawet, All About Meetings Inc., 2301 Artesia Blvd., Suite 12-101, Redondo Beach, CA 90278; 310-371-3438; fax, 310-371-1567.

Symposium on Electromagnetic Compatibility (SCV/EMCC); March 28–29; Santa Clara Convention Center, Santa Clara, Calif.; David M. Hanttula, 26787 Robleda Court, Los Altos Hills, CA 94022; 415-656-1661; fax, 415-683-0903.

Calendar

(Continued from p. 15)

Sixth International Conference on Indium Phosphide and Related Materials—IPRM (ED, LEO); March 28–31; Red Lion Resort, Santa Barbara, Calif.; Susan Evans, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331; 908-562-3896; fax, 908-562-1571.

National Radar Conference (AES, Atlanta Section); March 29–31; Holiday Inn Crowne Plaza Ravinia, Atlanta, Ga.; Robert N. Trebits, Georgia Tech Research Institute, 7220 Richardson Rd., Smyrna, GA 30080; 404-528-7769; fax, 404-528-7883.

Southcon '94 (Region 3, Florida Council); March 29–31; Orange Country Convention/Civic Center, Orlando, Fla.; JoAnn Lindberg, ECM, 8110 Airport Blvd., Los Angeles, CA 90045; 800-877-2668; fax, 310-641-5117.

APRIL

Second International Conference on Ultra-Wideband, Short-Pulse Electromagnetics (MTT); April 5–7; Weber Research Institute, Polytechnic University, Brooklyn, N.Y.; Lawrence Carin,, Polytechnic University, 333 Jay St., Brooklyn, NY; 718-260-3600; fax, 718-260-3136.

Southeastcon '94 (Region 3, et al.); April 10–13; Hyatt Regency Hotel, Miami, Fla.; Osama A. Mohammed, Department of Electrical Engineering, Florida International University, University Park Campus, Miami, FL 33199; 305-348-3040; fax, 305-348-3707.

Transmission and Distributed Conference and Exhibition (PE, Chicago Section); April 10–15; McCormick Place, Chicago; John J. Viera, Commonwealth Edison, Box 767, Chicago, IL 60690; 312-294-3333.

International Reliability Physics Symposium (ED, R); April 11–14; Fairmont Hotel, San Jose, Calif.; Ajit Goel, Oneida Research Service, 540 Weddell Dr., Suite 7, Sunnyvale, CA 94089; 408-734-2982.

Third Maghrebian Conference on Software Engineering and Artificial Intelligence (C); April 11–14; Hyatt Regency Hotel, Rabat-Agdal, Morocco; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013; fax, 202-728-0884.

Position, Location and Navigation Symposium—Plans '94 (AES); April 11–15; Bally's Hotel, Las Vegas, Nev.; Michael Hadfield, 12449 84th Way N., Largo, FL 34643; 813-531-5715.

International Symposium on Speech, Image Processing and Neural Networks (SP, Hong Kong Section); April 14–16; Hong Kong Convention and Exhibition Centre, Hong Kong; Chorkin Chan, Department of CS, University of Hong Kong, Hong Kong; (8+52) 859 7075; fax, (8+52) 559 8447; e-mail, cchan@csd.hku.hk.

International Conference on Requirements Engineering (C); April 18–22; Broadmoor Hotel, Colorado Springs, Colo.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013.

International Conference on Acoustics, Speech and Signal Processing (SP); April 19–22; Adelaide Convention Center, Adelaide, South Australia; Phil Plevin, Plevin & Associates Pty., Box 54, Burnside 5066, South Australia; (61+8) 379 8222; fax, (61+8) 379 8177.

Southwest Symposium on Image Analysis and Interpretation (SP, Dallas Section); April 21–22; Grand Kempinski Hotel, Dallas, Texas; Alireza Khotanzad, Southern Methodist University; 214-768-3101; fax, 214-768-3883; e-mail, kha@seas,smu.edu; or Nasser Kehtarnavaz, Texas A&M University; 409-845-8371; fax, 409-845-6259; e-mail, kehtar@ee.tamu.edu.

Rural Electric Power Conference (IA); April 24–26; Sheraton Colorado Springs Hotel, Colorado; Donald E. Werner, Omaha Public Power District, 444 South 16th St., Mall, Omaha, NE 68102-2247; 402-636-2585.

International Workshop on Computer-Aided Modeling, Analysis, and Design of Communication Links and Networks—Camad '94 (COM); April 24–27; Princeton Marriott Hotel, Princeton, N.J.; Benjamin Melamed, NEC USA Inc., 4 Independence Way, Princeton, NJ 08540; 609-951-2450; fax, 609-951-2499.

ACM Conference on Human Factors in Computer Systems (C); April 24–28; Hynes Convention Center, Boston; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013; fax, 202-728-0884.

VLSI Test Symposium (C, Philadelphia Section); April 25–28; Cherry Hill Hyatt Hotel, Cherry Hill, N.J.; Prab Varma, CrossCheck Technology, 2833 Junction Ave., San Jose, CA 95134; 408-432-9200; fax, 408-432-0907; e-mail, prab@crosscheck.com.

44th Electronic Components and Technology Conference—ECTC '94 (CHMT); April 30–May 5; Washington Hilton Hotel,

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Circle No. 19

Commentary

Reengineering government processes

(Editor's note: In this guest editorial, James Abrahamson, chairman of the board of Oracle Corp. and a retired U.S. Air Force lieutenant general, discusses the role of the aerospace and defense industries in today's "electronic commerce." The opinions expressed are the author's alone and not necessarily the positions or policies of the IEEE.)

The aerospace and defense industry of the United States and the Free World provided the corporate muscle, industrial means, and much of the intellect to defeat the most dangerous threat that mankind has ever faced. The basic structure and operating methods that broke the Soviet Union are worth reemphasizing. Allied governments and their military analyzed the threat and conceived counterforces to deter or defeat the adversary. In this critical phase, we executed studies combined with research that were mostly funded through small contracts or industry investment. Then we marshaled selected contractors and focused them on single weapon systems.

Because great sums of public monies as well as national security were involved, we established elaborate specifications and procedures to ensure fairness, honesty, quality, and performance. This required formidable human checks and balances, training, and documentation—mostly on paper—and produced the most capable and impressive military system ever.

But that era is mostly gone, a structure for yesterday, not tomorrow. In the United States alone, the defense industry that made such a valuable contribution to this incredible victory has lost about one-third of its jobs in the last five years and faces uncertain missions and savaged budgets. Yet threats remain, and our military forces need advanced technologies to protect us.

While each aerospace or defense company has its own strategy to deal with these changing times, they share a theme consistent with today's civil industry: reengineering processes, cutting costs, becoming more competitive and focused. The key element is how people work together and how they utilize one of the most valued assets of any human endeavor: information.

Amid the convergence of computers, advanced telecommunications, and highly capable software, nondefense industries have begun to group opportunities for new processes under the title "electronic commerce." Fortunately, the U.S. Department of Defense (DOD), the defense ministries of several allied nations, and the North Atlantic Treaty Organization (NATO) are following suit with Continuous Acquisition and Life-cycle Support (CALS). Started in 1986, it has matured into a major effort to convert that government legacy—paper-based plans, engineering data, and manuals—into electronic form and to streamline and transform acquisition and logistics activities.

Realizing that it must switch from military to civil specifications and procedures, DOD has asked that the National Securities Industry Association sponsor a separate, dedicated CALS Industry Steering Group. It comprises several thousand volunteers and several hundred companies.

They are organized like a corporation with divisions developing standards, studying processes, rewriting government procurement regulations and guidelines, and educating others with evangelistic fervor. Further, the movement has become a strong international force, with CALS groups in Europe, Canada, and the Pacific Rim.

How might a future CALS environment affect the structure and style of doing things in the aerospace and defense industry? Imagine this scenario:

A government industrial and procurement structure is in place so that in Richmond, Va., at the Defense Supply Center there, a logistics manager has at her fingertips for display on her computer screen the global inventory of rotor head parts for the UH-60 Blackhawk helicopter. Instead of analyzing annual usage and logistic support requirements and then procuring a year's supply of parts, she has an active projection that takes into account failures, wear-out rates, and war-readiness reserves.

With this tool, connected directly to every Blackhawk base around the world and continually projecting short-term needs, she need not wait for a single large buy and its complex bidding process. Instead, she can electronically notify a group of companies that have already demonstrated that they have fully automated production and can meet quality requirements. She electronically transmits production setup information and the number of parts needed. The companies respond electronically with low, "nearly commercial" prices because the minimal interruption occasioned by this small job is readily accommodated by the high-volume commercial manufacturing they already have under way. She selects the low bidder and allows a one-week delivery adjustment to fit its nearly 24-hour manufacturing schedule. The vendor automatically transforms the set-up data into automated instructions to machinery on how to cast, cut, and polish.

As work is finished, quality data and test certification are automatically transmitted to the logistics manager to become part of that company's permanent record. If the logistics manager is satisfied with the buy and manufacturing data, she touches an "accept and pay" icon on her screen. The action automatically pays the company and provides direct shipping instructions.

This scenario is nearly a reality. The Richmond center has converted much of its paper data into electronic form and demonstrated the ability to transmit and describe helicopter rotor head parts and conduct some electronic commerce. Even more striking, when coupled with some of the Clinton administration's defense initiatives, this capability has reinvigorated the Richmond center and created an incredibly entrepreneurial spirit there, along with significant savings to taxpayers.

Notice that this scenario has no on-site or roving cadre of government inspectors or elaborate certification of the company's financial system. And the companies have been pleased to participate in even a tiny government contract because it parallels their civilian core business and minimally interrupts normal production, and because the government pays the bill instantly and electronically.

The idea that government project managers could pay bills directly is not so radical. Who can more responsibly judge and administer payment than the individuals in charge of any project? In fact, process changes and cost savings that may be available in the era of electronic commerce could be outstanding. Improvements also are possible in small-business contracting, research and development, large acquisitions, and the daily administration of large contractors.

Fundamental change is coming in manufacturing industries, and the aerospace and defense industry must not be left out. Free nations cannot afford to have their vital industries left behind because of difficult changes as we adapt our security system to a different, but still dangerous and uncertain world.

James A. Abrahamson

James A. Abrahamson is chairman of CALS Industry Steering Group. He is a former director of the Strategic Defense Initiative Organization and former Associate Administrator of NASA..

ANALYSIS AND FORECAST ISSUE

Technology 1994

John Mattos

- ☐ *Telecommunications*
- ☐ *Data communications*
- ☐ *Consumer electronics*
- ☐ *PCs and workstations*
- ☐ *Software engineering*
- ☐ *Application software*
- ☐ *Large computers*
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- ☐ *Power and energy*
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No matter what the field, the theme underlying much technical development last year and this is almost an oxymoron: an intertwining of competitiveness and compatibility. While companies want their high-tech products to edge out the competition, they are realistic enough to realize that this is the age of multivendor systems. Thus, to ensure their own survival, they are designing hardware and software to work with everyone else's.

For example, the long-anticipated merger of PCs and workstations became a reality as reduced-instruction-set computing (RISC) chips became central processors in both types of systems. Microsoft's new release, Windows NT, will run on the PowerPC developed by Apple, IBM, and Motorola, on MIPS R4000 processors, on Sun UltraSparc workstations, on Intel-based PCs and clones, and on the Alpha processor from Digital Equipment.

Trudy E. Bell Issue Editor

An even stronger example of compatible competition is multimedia, where numerous competing developers of computer hardware and software agreed to support the peripheral component interconnect (PCI) local bus.

For high-end computing, open client-server systems is the name of the game. Last year IBM redefined both its mainframe and midrange offerings as superfast, large-scale file servers for, say, workstations linked in local-area networks. The cross-platform capability of the operating systems has created a veritable groundswell in the development of Windows NT application software.

In test and measurement, a new industry alliance was formed dedicated to increasing ease of use for multivendor VXI systems users. Meanwhile, in consumer electronics, nine organizations formed a Grand Alliance to develop a digital standard for high-definition television (HDTV).

In medical electronics, the European Commission issued a directive to enable companies in the European Union (formerly Community) to have barrier-free home markets to reduce unit costs. Manufacturers in other nations will have to meet European Union standards to sell equipment in Europe.

In industrial electronics, industry leaders are standardizing the way products are modeled in software, allowing organizations with different computers and application software to exchange product data—a boost to transnational concurrent engineering.

The trend in data communications is toward the interactive convergence of data, audio, and video—and of both consumer and business networks. In telecommunications, the trend is toward the commercialization of an optical-fiber superhighway with distributed optical amplification. In both, wireless applications are a bold new frontier.

In power and energy in the United States, electric utilities are facing a fundamental transition as a result of the sweeping Energy Policy Act of 1992: they have to grant all generators—most of which are unregulated—access to the transmission network, while still keeping the system integrated.

Meanwhile, productivity was a key theme in solid-state technology, where computer-integrated manufacturing systems are expected to improve the quality and yield of semiconductors. Also, multichip modules have proven themselves commercially feasible.

In software engineering, the term CASE has fallen from grace for its failure to be the panacea for low software productivity. Function points have replaced older methods of measuring productivity as a result of new programming techniques.

In transportation, flywheel-based electromechanical batteries emerged as a strong alternative to electrochemical batteries for electric vehicles. Several intelligent vehicle-

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highway systems finished successful field tests. And Motorola announced the first single-chip multiplexed system and serial bus to reduce the wiring in automobiles.

For civilian and military aerospace, people are hoping 1994 will be better than 1993. Five major spacecraft were lost in space. On the plus side, the launch of the one-third-scale DC-X [see cover] demonstrated the potential for a single-stage-to-orbit vehicle. As to the military, the space-based Strategic Defense Initiative (SDI or Star Wars) program officially ended after 10 years and US $30 billion, and the SDI Office became the Ballistic Missile Defense Office. ◆

THE MEDIA EVENT

"Donahue." "Hard Copy." "Nightline." "The Simpsons." "Doonesbury." *The New York Times.* Local newspapers. In 1993 they all discovered virtual reality and told the world. Virtual reality—and its ability to immerse users in interactive three-dimensional worlds—was presented as amazing and miraculous, both a salvation and a danger.

"You can actually interact with another person in virtual reality, you can make love to the other person," said Phil Donahue in a broadcast last May.

"Virtual reality will be the sex toy of the coming century," stated Joan Stavely, identified as a virtual reality expert, on the syndicated television show "Hard Copy."

"Will virtual reality transport millions of us into an addictive world of make-believe?" asked Ted Koppel on ABC's "Nightline."

And the highly publicized ABC miniseries "Wild Palms" purported to portray Los Angeles in the year 2007, where a politically ambitious television network is broadcasting virtual reality (VR) as interactive holograms, with disastrous consequences.

Meanwhile, on the cartoon show "The Simpsons," character Lisa envisioned her town spending US $3 million to improve education through virtual reality. In history class, Lisa foresaw herself putting on a helmet and joining the Mongol horde of Genghis Khan.

For researchers developing useful applications of virtual reality—like architectural walkthroughs, automotive design, aircraft maintenance simulation, acrophobia therapy, and molecular modeling of pharmaceuticals—this media attention was both a boon and an embarrassment.

On the plus side, said Thomas A. DeFanti, director of the Software Technologies Research Center and codirector of the Electronic Visualization Laboratory at the University of Illinois at Chicago, "virtual reality is getting into people's consciousness. People are now talking about funding virtual reality in a way they never talked about funding visualization, and that's exciting."

Overall, Jaron Lanier, a pioneer of virtual reality who is now pursuing research in its application to medicine and to programming environments, said, "The press has helped us. In a time of shrinking funds, when all science is competing for funding, there is an element of marketing involved."

Said Myron Krueger, another pioneer in the field who is now president of Artificial Reality Corp., Vernon, Conn., "Virtual reality would not exist as a field without the relentless attention of the press." However, he is concerned that the media, by portraying the most sophisticated, far-out applications of virtual reality, is setting the researchers up for a fall. Compared to the media's version, he told *IEEE Spectrum*, "the technology itself is disappointing when you see it."

The focus on sex is unfortunate, and hypothetically could impact funding, DeFanti said. In fact, virtual reality is more involved with advanced mathematics, portraying concepts from non-Euclidean geometry, say.

One effect of the media attention has been a broadening of the definition of virtual reality. Initially used only for systems with helmet displays and control gloves that fully immersed users in interactive worlds, the term is now used to describe everything from augmented reality (looking through a display at the real world but with some computer information superimposed on it) to telepresence (remotely controlling a robotic device) to three-dimensional movies. Indeed, William Bricken, principal scientist at the Human Interface Technology Laboratory at the University of Washington, Seattle, told *Spectrum*, "It has become common on the street for people to equate virtual reality with computer graphics in general. They had no word for those flying logos. Now they call them virtual reality."

This concerns Bricken. "Partial application of a paradigm undermines the paradigm," he said. "The more flying logos and virtual reality are confused, the less people will understand what virtual reality is all about."

Lanier, who coined the term virtual reality, told *Spectrum* that the reason he liked the term was that "I recognized that it had some popular mojo and I felt that was a good thing."

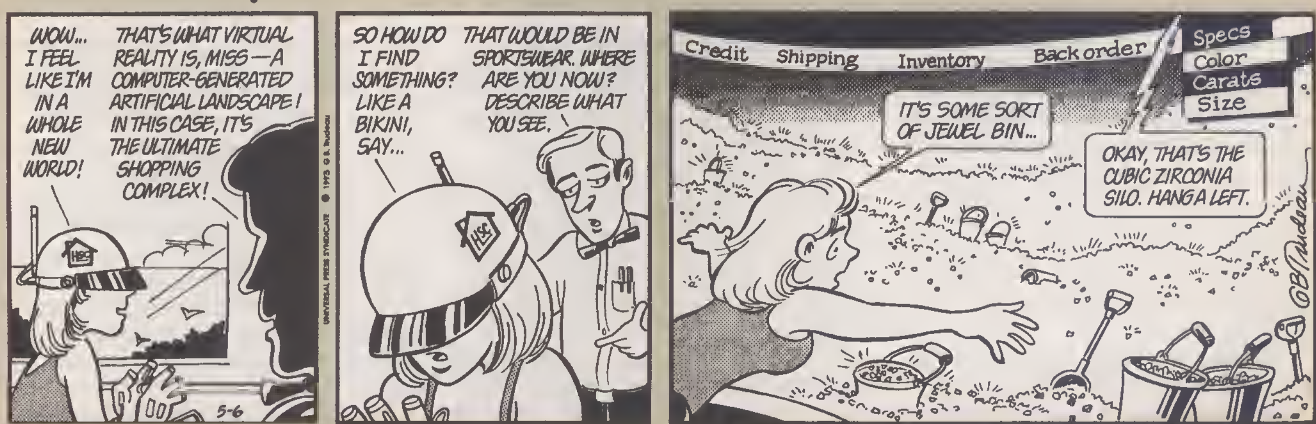
"It is inevitable that the meaning of terms goes through periods of being more specific and more general," he said, "though I have seen some particularly egregious uses of it—like to refer to a spreadsheet."

Perhaps the virtual reality video game is the version being experienced by most people, though it usually offers limited immersion or interaction. A number of arcades around the world have installed virtual reality systems.

Virtual reality in the arcade down the street, on popular television, and in all the newspapers is a natural extension of a field that has been exciting researchers for years. But, said the University of Washington's Bricken, it means that "virtual reality [for the research pioneer] is dead. It is no longer the subject of interesting, groundbreaking, startling, philosophical debate. It was all that, but [it] has now turned into just another engineering job. The pioneers are moving on to study human interaction and experience within the virtual domain."

—Tekla S. Perry, Senior Editor

Doonesbury BY GARRY TRUDEAU



Telecommunications

A review of the U.S. telecommunications industry's last decade indicated that the 1984 Bell System breakup had completely the wrong rationale. In Europe, the state-owned telecommunications authorities of most nations agreed to become privately owned companies by Jan. 1, 1998. And around the globe, but especially in Asia, cellular and wireless personal communications services expanded.

On the purely technological front, optical fiber dazzled. "Dark fiber"—fiber installed without electronic amplifiers—began being laid in Europe and the United States as the first stage in a data superhighway. Solitons also made it into the real world, when the first long-distance optical-fiber system to be based on these virtually incorruptible light pulses began operation.

A BELL TOLLS. Jan. 1, 1994, marked the 10th anniversary of the breakup of the Bell System into the present-day AT&T Co. (which offers long-distance services and is free to enter the unregulated computer and information-technology markets) and the seven regional "Baby Bell" holding companies (which offer regulated local services and were initially barred from manufacturing and marketing information-technology services, and from offering most forms of long-distance service). The theory behind the 1984 divestiture was that low-volume, local exchange service was a natural monopoly and that high-volume, long-distance service was naturally competitive ["The Decision to Divest: Incredible or Inevitable?," *IEEE Spectrum*, November 1985, pp. 46–55].

"But it is now clear that the assumption was wrong," declared Peter W. Huber, Michael K. Kellogg, and John Thorne in *The Geodesic Network II: 1993 Report on Competition in the Telephone Industry*, a comprehensive report issued for the divestiture's 10th birthday. "In fact, it was worse than wrong: the architects of the Bell divestiture got it backwards. If there is going to be a monopoly, it will be in the long-distance market. The local exchange should be—and soon will be—competitive."

The report is a sequel to 1987's *The Geodesic Network*, which the U.S. Department of Justice published as part of a post-divestiture obligation—namely, to review every three years the continued necessity for restricting the Bell operating companies' lines of business.

Trudy E. Bell Senior Editor

"The once monolithic Bell network, with a simple vertical ladder of nodes (telephones, local exchanges, long-distance exchanges) and connections between them (typically over metal wires and microwave links), is giving way to a network of networks," with equipment and transmission media supplied by scores of manufacturers, Huber and his colleagues noted.

Most investment today is in the hardware and software at the periphery, not in one network provider's central office. As a result, "a market once dominated by centralized supply is now controlled by dispersed demand," with common standards produced through competition in the international marketplace. Huber and colleagues predicted that "within a decade at most, and more likely five years or so, the divestiture decree will have to be abandoned."

DOWN WITH MONOPOLIES. In the next four years, a score of national public telecommunications operators (PTOs) are likely to convert from state-owned monopolies to market-driven privately owned corporations. A decade ago, most of western Europe's PTOs were effectively government departments, generally grouped with postal services into a single state communications utility. Now, most are no longer associated with postal services. Moreover, on June 16, the European Union (formerly Community) agreed that by Jan. 1, 1998, existing nationally owned voice telephony operators would be exposed to competition in their home markets.

HIGHLIGHTS

- European telecom authorities going private
- Wireless systems burgeon in Asia
- Fiber amps hit the marketplace
- Cable TV marries wireless telephony

The 1998 deadline applied to eight out of the 12 Union countries; Greece, Ireland, Portugal, and Spain were given an extra five years' grace period because they were judged to have less developed networks. Nonetheless, even those four are moving as quickly as they can.

By the middle of the year, with the last sale of government-owned shares, British Telecommunications PLC became fully private and now operates in most open and competitive markets worldwide. The PTOs of Belgium (Belgacom), Finland (Telecom Finland), France (Telecom France), Ireland (Telecom Eireann), and Sweden (Televerket) have either already been given the status of corporations (albeit state-owned ones), or soon will be. Amendments to the German constitution are being introduced in the German legislature, with a first stake in Deutsche Telekom to be offered in 1996. The PTOs of Denmark (Tele Danmark), Greece (OTE), Holland (KPN), Italy (Stet), Portugal (TLP), Spain (Telefónica), and Turkey (PTT Turkey) have also taken steps toward privatization.

In many cases, this haste recognizes that competition already exists in the PTOs' home markets. Almost all the European Union nations have cellular mobile services competing head-to-head with the PTOs. Whereas the first generation of analog cellular services were provided by the PTOs themselves, the licenses for the new digital services built to the pan-European standard GSM (Groupe Spécial Mobile) have in most nations been granted to two operators: usually the PTO and one private consortium, which often includes overseas companies. (This is also true of Eastern Europe—see table, opposite page.)

The Union plans to publish a Green Paper—a proposal to be mulled over by the European parliament—by the end of this year, examining what the new European telecommunications infrastructure, cable television networks, and wireless telephony included, should look like.

ASIA GOES MOBILE. Mobile communications have grown fastest where few phones went before: in Eastern Europe and Asia. Instead of digging up roads and laying down cables, which would take months or even years, the plan has been to erect base stations for wireless communications that can connect people within a day.

And so it has happened. But the pattern in the two regions is vastly different, according to a special report on mobile communications that appeared in the Sept. 8, 1993, issue of London's *Financial Times*.

Although mobile telephone networks have been built in just about every capital city in Eastern Europe over the past two years, the services are expensive, even by Western standards, and only a few government officials and foreign executives can actually afford them.

There are now 11 cellular phone networks operating in central and Eastern Europe, run by joint ventures between the local telephone

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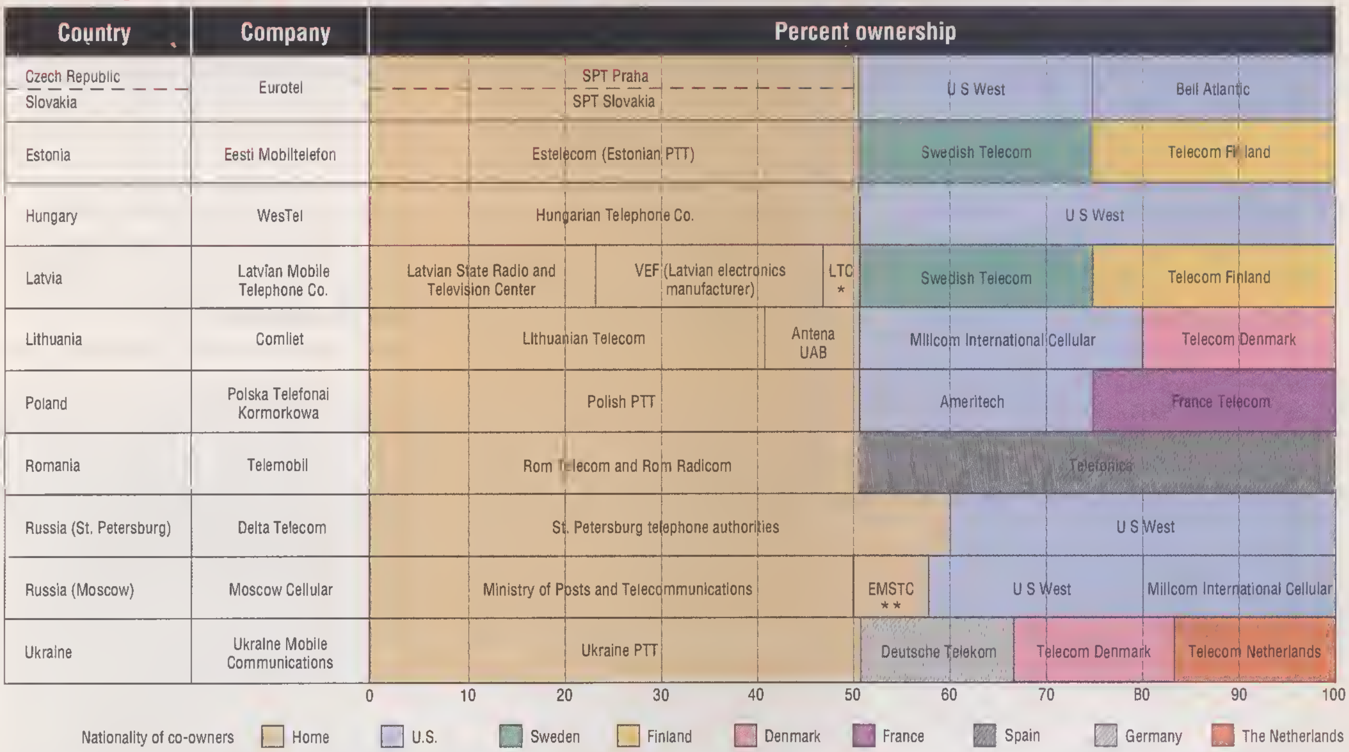
Ownership structure of Eastern European cellular telephone operators



*Latvian Telecommunications Center **Eye Microsurgery Science and Technology Complex of Moscow

Source: *Financial Times Mobile Communications*, Bell Atlantic Corp.

Eastern European cellular telephone systems are being installed by international joint ventures. In almost all cases, one or more entities in the home country retain 51 percent of system ownership, while 49 percent is owned by at least one Western European or U.S. company.

operator (which usually retains a majority interest) and one or more foreign telephone companies. Altogether, they serve some 60 000 subscribers in markets with a combined population of 115 million (a penetration of 0.05 percent). Western Europe has over 7 million cellular subscribers in markets with a combined population of 350 million (a penetration of 2 percent).

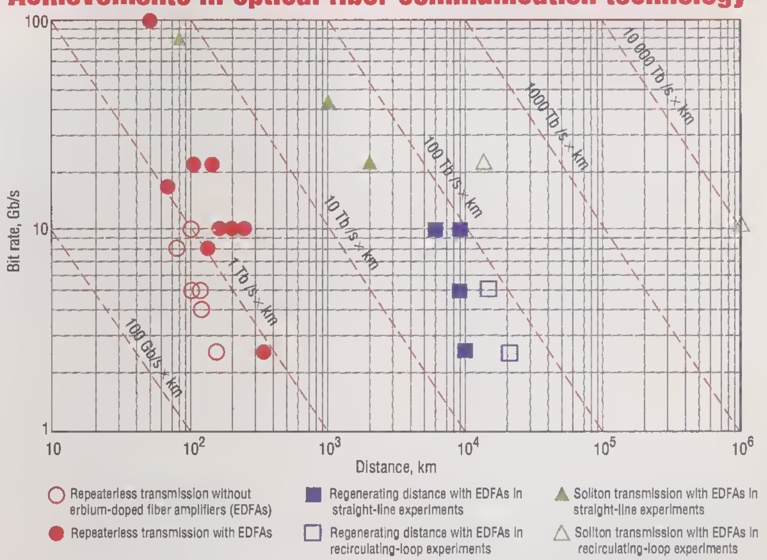
In contrast, by the beginning of the year, Asia and Australasia had more than 4 million mobile telephone subscribers in markets totaling more than 1 billion people (a penetration of 0.4 percent). Although Japan alone accounts for 40 percent of subscribers in the region, China has grown the fastest: 526 percent between Jan. 1, 1992, and June 30, 1993—from 38 000 to more than 200 000 subscribers. All but five of China's 30 provincial state-owned telephone operators have cellular telephone networks. The numbers of subscribers in Australia, Indonesia, Malaysia, Singapore, South Korea, Taiwan, and Thailand have also grown by more than 50 percent, just from January 1992 to January 1993 [see table, p. 25].

IRIDIUM TAKES OFF. The dream of holding in the palm of one's hand a terminal accessing a truly global mobile communications service moved closer to reality in August when Motorola Inc., Schaumburg, Ill., won financing for its US \$3.4 billion Iridium telecommunications system, perhaps the world's largest private aerospace project.

Companies and PTOs from North and South America, Europe, and Asia agreed to provide \$800 million in the first stage of financing; Motorola itself has already invested another \$270 million. Participants include Mawarid (a Saudi Arabian industrial group), Mitsubishi, Mitsui, Raytheon, Sony, Sprint, and Stet (the holding company for Italy's domestic and international telecommunications business).

Iridium differs from most mobile telecommunications systems in relying on satellites in low earth orbit—or LEO—instead of geostationary orbit: in other words, at altitudes of 900–10 000 km instead of 36 000 km. Voice transmission via LEO satellites is expected to suffer less from the echo found on some geostationary satellite links, be-

Achievements in optical-fiber communication technology



Source: Tran V. Muoi, Pco Inc.

Bit-rate-distance product—a figure of merit for comparing fiber-optic systems—tops 100 terabits per second × kilometers for a transmission experiment sending solitons through a fiber that includes erbium-doped fiber amplifiers. Solitons are optical pulses that have been shown to travel without distortion through more than 1 million km of fiber.

cause the round-trip signal time to LEO satellites is less. More important, because the satellites are closer to the earth, the user's handset will require less power for transmitting and receiving signals, and so can be smaller, lighter, and cheaper.

But coverage of the entire earth requires many more LEO satellites than the standard three geostationary ones. The Iridium system is to comprise 66 of them. Current plans call for launching them over two years beginning in 1996; commercial service is to begin in 1998. It is hoped that the system will attract as many as 1.5 million subscribers by the end of the decade—an estimated 1.5–2 percent of all cellular subscribers.

In addition to Iridium, five other U.S.-based consortia have proposed their own LEO-based schemes. At present, though, they are working to obtain financial backing.

The Iridium system and its competitors, which will all be using frequencies above 1 GHz, are dubbed "Big LEO" systems. There is also a class of Non-Voice Non-Geostationary (NVNG) Mobile Satellites Services—LEO satellites operating below 1 GHz that have come to be known as "Little LEO" systems. On Nov. 16, they were allocated spectrum in the 150- and 400-MHz bands. The three NVNG license applicants are Volunteers in Technical Assistance (VITA), a nonprofit aid organization that is based in Arlington, Va.; Orbital Communications Corp., in Dulles, Va.; and Starsys Global Positioning Inc., located in Washington, D.C.

The NVNG service, based on technology pioneered by radio amateurs, will be used for brief data messages, monitoring and control of remote industrial, agricultural, and natural resource facilities, and consumer alarm, electronic mail, and vehicle location. Launches of the first NVNG satellites are expected later this year.

CABLE AND WIRELESS. After years of bickering and jostling for position, cable television

COCHRANE: Dark fiber will transform telecommunications

VIEWPOINT

This will be the year of the "dark fiber" —a transparent superhighway or information "hose" unimpeded by electronic amplifiers or switches, through which gigabits per second of data can be "poured." Last year, the Federal Communications Commission (FCC) ruled that three of the regional Bell operating companies handling local service would have to supply direct optical-fiber links between customers on an experimental basis. That ruling was reinforced by the announcement of the Clinton administration's support for the development of a national gigabit data highway. Meanwhile, the cost of passive optical networks fell, so that fiber to the home, at last, became economically competitive with traditional twisted copper pairs.

Together, these three developments catapulted into public awareness the revolutionary implications of transparent optical networks for telecommunications, computer and information networks, and even entire national economies. For the first time, we are witnessing a convergence of key technologies, market needs, and costs that will finally allow the economic introduction of transparent optical networks.

In fiber technology, the key to the low cost and high bandwidth of transparent optical networks is the replacement of electronic repeaters with optical amplifiers. Today's electronic repeater converts the detected optical signal into an electric signal that is amplified to drive a semiconductor laser, which then regenerates the optical signal for the next stretch of fiber. The limitations of the electronic circuits involved present a restricted and finite signal bandwidth in the fiber path.

In contrast, optical amplifiers can boost a wide range of wavelengths with no intervening photon-electron conversion. The most revolutionary and promising type is simply a length of optical fiber. Optically pumping doped or undoped fiber in a cable now yields amplifiers more than 50 km long. Such distributed amplification offers the best end-to-end signal-to-noise ratio.

All this translates into cheaper operation. For one thing, optical amplifiers reduce the number of switching sites in a fiber cable by a full order of magnitude as the signaling, transmission, and reliability constraints of copper cables are overcome. A less obvious benefit is that a transparent passive optical network limits human interference within the network. Typically about half the faults in a telephone company's network are in its copper local loop. About 25 percent are induced by re-routing, repair, and routine maintenance. In other words, installation and repair crews actually introduce faults directly, and also leave latent faults and other damage. Corrosion contributes a further 10 percent, wind damage to overhead wires about 5 percent, and damage by other utilities workers digging nearby a good 10 percent.

'In fiber technology, the key to the low cost and high bandwidth of transparent optical networks is the replacement of electronic repeaters with optical amplifiers'

Optical fiber, and particularly passive optical networks, do not require physical reroutings, as they can be externally rerouted by wavelength and/or time slot address. This has two significant advantages. First, they have the potential for decreasing induced faults by some 40 percent compared with copper. Second, once a transparent fiber is installed between hubs, it can stay put essentially forever without future rerouting or new electronics (except at the terminal ends). In economical terms, therefore, passive optical networks are superior to all other solutions, including fiber to the curb and wireless to the home.

The year was also distinguished by numerous demonstrations of microwave radio broadcast directly over fiber. They showed that radio cells can be coupled into transparent optical paths and replicated (rebroadcast) at vast distances from the transmitter without much intermediate technology.

Even more interesting, optical wireless systems utilizing semiconductor- and fiber-based technologies demonstrated that huge bandwidths can be realized in free space. New forms of holographic lensing (essentially, optical antennas) and optical "leaky feeder" allow cells for wireless systems to be created that range in size from the diameter of a room down to that of a pinhead. With this technology, it is feasible to have wireless office systems in which diffuse optical fields give a uniform signal power everywhere in the room. Alternatively, the office systems may focus signal power on specific equipment, broadcasting data to and from individual desks and computers. With light, it is now possible to transmit the entire contents of the Encyclopaedia Britannica (1 gigabit of information) into a shirt-pocket-sized device in less than one second.

All these optical developments are setting telephone companies and computer network providers at odds. Until last year, the conflict seemed straightforward: telecommunications people speak in terms of switching, computer users in terms of routers. What the computer community requires is dark fiber, or a superhighway, that allows unimpeded transmission with no switching or electronics getting in the way. Conversely, the telephone companies wish to maintain control of their networks by owning the switches, plus the intelligence at the core of their network that controls calls and the allocation of bandwidth.

The probability is that neither camp will win, because in all likelihood a successful system design will be a melding of both. Intelligence is rapidly migrating to the periphery of networks (in the form of smarter terminals and applications), and the need for such central functions as switching and intelligence is diminishing. That trend will probably become more pronounced between now and the year 2000.

Today, the chief impediments to the suc-

companies and telephone companies decided that they would be stronger in the nascent multimedia market as partners than as competitors. On Oct. 13, the largest communications merger in U.S. history was announced: Bell Atlantic, the regional Bell holding company for the mid-Atlantic states, would buy TeleCommunications Inc. (TCI), the nation's largest cable-TV operator, along with its cable-programming sister company Liberty Media Corp., for $12 billion in stock.

Because of a provision in the 1984 Cable Act barring a telephone company from owning and operating cable-TV stations in the same geographical area as it serves telephone customers, TCI plans to divest itself of the 14 percent of its 13.2 million subscribers who are in Bell Atlantic's territory. (That plan may be more a precaution than a necessity: not two months earlier, on Aug. 14, in a landmark court decision, a Federal judge ruled that the 1984 Cable Act provision violated the constitutional right to free speech, and allowed Bell Atlantic to offer cable-TV service in Alexandria, Va.) Nonetheless, even without those subscribers, the merger would give the new Bell Atlantic more than 22 million cable and phone customers in 59 of the top 100 U.S. markets.

Most important, the two companies are bent on revolutionizing home entertainment and information by turning Bell Atlantic's telephone network into a "video pipeline," and elsewhere rebuilding TCI's cable systems to handle telephone service. Moreover, Bell Atlantic plans to use TCI's cable system as a backbone network for personal communications services (PCSs), a new generation of wireless phone service.

The announced Bell Atlantic–TCI merger would dwarf other recent alliances between telephone companies and cable-TV companies, including the the $1.2 billion investment of Nynex Corp. in Viacom Inc. and the $2.5 billion investment by U S West Inc. in Time Warner Inc. For the merger to be finalized, however, Bell Atlantic must secure court waivers from the terms of the divestiture decree breaking up AT&T in 1984, because the satellite system used by cable operators to distribute programming is considered a form of long-distance service.

OPTICAL FIBER ADVANCES. This was the first year that fiber-in-the-loop gained momentum in practical applications, according to Paul Shumate of Bellcore, Morristown, N.J. Many of the Bell regional holding companies announced long-term plans and let contracts for access to fiber-in-the-loop equipment that, if cost-effective, may ultimately lead to the delivery of multimedia applications.

Distributed erbium-doped fiber amplifiers (EDFAs) remain crucial to future optical-fiber communications, according to Tran V. Muoi, chair of the IEEE's Lasers and Electro-Optics Society's Optical Communications Technical Committee. An EDFA is a length of ordinary silica fiber doped with the rare-earth element erbium to give the fiber gain. When optically pumped with light from an outside semiconductor laser, the erbium-doped fiber boosts the power of all signals traveling through it within a relatively wide range (25 000 GHz) of wavelengths centered on 1.55 μm.

When these devices serve as optical-power booster amplifiers at the transmitter site and optical preamplifiers at the receiving site, a signal can traverse twice its usual distance without needing a repeater. A number of commercial transmission systems—primarily for submarine use—were announced for systems using EDFAs; in addition, the first such amplifiers used in an AT&T network were installed in a link between San Francisco and Point Arena, Calif., which began service last June.

The advent of EDFAs has also fanned interest in the commercial viability of systems relying on solitons—pulses that retain their shape for thousands of kilometers of optical fiber because of the reciprocal effects of chromatic dispersion and an index of refraction that changes with intensity ["Light that acts like 'natural bits'," *Spectrum*, August 1990, pp. 56–57 and "Molding light into solitons" by Hermann A. Haus, *Spectrum*, March 1993, pp. 48–53].

Using EDFAs as in-line nonregenerating repeaters in 1992, M. Nakazawa and his colleagues at Nippon Telegraph & Telephone's Transmission Systems Laboratory in Tokai, Japan, transmitted solitons at a rate of 10 Gb/s over a distance of 1 million kilometers. And last April, Nakazawa reported at the 1993 Optical Fiber Conference that, practically speaking, soliton transmission would be effective over unlimited distances, as in a fiber the signal could encircle the earth some 22 times before the signal-to-noise ratio rendered it unusable.

Erbium doping, however, amplifies signals only at the wavelength of minimum attenuation in the optical fiber (1.55 μm). So researchers are actively investigating the possibility of fiber amplifiers that operate at the wavelength of minimum chromatic dispersion (1.3 μm). So far the most promising candidate is praseodymium-doped fiber amplifiers: a signal gain of more than 25 dB has been reported by several laboratories. ◆

Cellular-subscriber growth around Pacific Rim

Largest markets	Subscriber thousands, as of January: 1992	1993	Percent growth
Japan	1251	1615	29
Australia	336	559	54
Taiwan	199	429	116
South Korea	173	271	56
Thailand	154	257	67
Hong Kong	180	233	29
Malaysia	135	207	53
China	38	160	321
Singapore	70	111	59
New Zealand	69	94	36
Philippines	40	55	38
Indonesia	16	32	97
TOTALS	**2688**	**4022**	**50**

Source: *Financial Times Mobile Communications*

cess of future data highways are, first, the lack of cooperation between the telecommunications and computer industries, and second, standards that are dead on arrival, strangled by protocols and operating systems from the computer industry that are tied to the 1960s.

Since 1980, optical-fiber transmission capabilities have doubled every year, while costs have dropped exponentially. Such progress should continue beyond the year 2000. Throwing bandwidth at problems such as signaling, control, and network management naturally suggests that wavelength division multiplexing (multiplexing signals by color of light) should supersede time division multiplexing (multiplexing by sampling signals in time). It may also be that the current contest between soliton propagation as a means of transmitting undistorted signals around the planet, and wavelength division multiplexing, which incurs some significant distortion, will be resolved by a mixture of the two technologies. Asynchronous transfer mode (ATM), or packet-switching techniques, at a photonic level might also prove optimal for a massive global telecommunications network.

Such a solution would be free of the delays, blocking, and information waves that are inherent in ATM realized electronically over restricted-bandwidth systems using radio, copper, and fiber with an electronically limited bandwidth. Now, however, that idea looks as revolutionary as suggesting dropping the code compression of signals because the bandwidth restrictions of copper are no more. Who knows, in a decade we may see the realization of such radical solutions promoted by passive and transparent optical networks—and then we will really be able to telecommunicate!

Peter Cochrane (F) is head of The Core Technologies Research Department at British Telecom Laboratories at Martlesham Heath, Ipswich, UK. In 1990, he received the Queen's Award for Technology in recognition of his accomplishments as manager of production of optical receivers for the TAT-8 and PTAT-1 undersea cable systems.

Data communications

Events in the consumer market and the business world have recently shaped—and for the next few years will continue to shape—this area far more than technological breakthroughs. The need for real-time delivery of much higher volumes of data to meet the video and audio requirements of coming multimedia applications drove developments in data speed and in that new realm of technology where data communications converge with other kinds of inputs. Similarly, a rising interest in increasingly mobile communications sparked an interest in wireless communications.

PARAMOUNT CONCERN. Speed is always crucial in data communications. In the research community, the Aurora gigabit research network successfully started transmitting data and video signals over its synchronous optical network (Sonet) backbone. In the commercial arena, the most important speed-related news was the exponential leap of interest in and commitment to asynchronous transfer mode (ATM).

By the end of last year, more than 300 members had joined the ATM Forum, an organization of vendors working both on solidifying the ATM specification and on developing ATM products of their own, at a clip of three or four enrollments a week. One proof that ATM is entering the mainstream was the announcement by Synoptics Communications Corp., Santa Clara, Calif., of the LattisCell switch, the first commercial piece of ATM gear priced below $1500 per port. Yet the widespread deployment of ATM is still many years off [see figure, top of next page]. As Chase Bailey, president of Efficient Networks Technologies Inc., Dallas, pointed out, ATM signaling, call connection, routing, and addressing have not yet been worked out, and neither has the specification for lower-speed implementations.

Some of the most interesting efforts to improve the speed of data communications gear involved standards for higher-speed (100 Mb/s) Ethernets. ATT Microelectronics, Berkeley Heights, N.J.; Hewlett-Packard, Palo Alto, Calif.; and IBM are pushing 100Base-AnyLAN/IEEE 802.12 (formerly 100Base-VG) whose competitor is 100Base-X/CSMA-CD (IEEE 802.14, formerly IEEE 802.30), promoted by Ungermann-Bass Inc., Santa Clara, Calif.; 3Com Corp., Santa Clara, Calif.; and Grand Junctions Networks, Union City, Calif. The former product permits delay-sensitive network traffic to be given higher priority, but 100Base-X/CSMA-CD retains the original Ethernet protocol, implying greater backward compatibility with existing Ethernet. Stable drafts of both standards are predicted for the first half of 1994, but only the market can determine which version will work better with the new multimedia network applications expected to arrive throughout the year.

Paulina Borsook Contributing Editor

Lyman Chapin, chief network architect at Bolt, Beranek, and Newman (BBN), Cambridge, Mass., said that these competing standards "push back the date when new WAN technology [such as ATM] will be necessary to be deployed in local-area networks." Consultant John Krick, an analyst with Datapro Research Inc., Delran, N.J., said that "the major effect of this interest in fast Ethernet could be to drive the price of FDDI [fiber distributed data interface] down."

The real significance of the Ethernet and ATM developments may lie elsewhere, however. Dan Simone, senior project manager at Synoptics, said that "the importance, really, is the introduction of switching, whether with frames such as Ethernet or cells such as ATM. With people moving away from shared media, you're going to have to manage and troubleshoot networks differently. One of today's network monitors wouldn't hear anything on a switched network, because there is not a common collision domain."

Simone pointed out that the move toward switching is also pushing what he calls "virtualization" of networks—segments of local-area networks (LANs) that are defined by software—so workstations that share a common LAN do not have to share a common location. "Soft segments," as opposed to physically separate hub backplanes, will be the result, and the administrative burden of adds, changes, and moves will thus greatly diminish.

HIGHLIGHTS

- **ATM dips its toe in the mainstream**
- **Internet becomes a household word**
- **The public gets its first look at PDAs**
- **Everyone is talking about multimedia**

MORE VISIBLE. The Internet has not only become ever more visible and commercialized—a cartoon about it showed up in *The New Yorker*—but also continued to create new services. Internet Talk Radio, a weekly series of downloadable audio files professionally produced as radio programs, premiered last year. The Mbone, the Internet multicast backbone, has gone on doubling in size every few months, though as router vendors build multicast capacity into their products over the next few years, the need for the Mbone will go away. Two-way Internet access became available through a cable television interconnection, a service offered by Cablevision Systems Corp., Woodbury, N.Y., and Performance Systems Inc., Reston, Va.

Brian E. Carpenter, group leader for Communications Systems of the Computing and Networks Division at the European Organization for Nuclear Research (CERN) in Geneva, said that the WorldWide Web (WWW), a hypertext client-server–based cross-referencing tool initiated by CERN, "has become the fastest-growing information service on the net." Originally aimed at the high-energy physics community, WWW consists of documents and links plus a simple protocol with whose aid browser programs can request a keyword search by a remote information server. (Further information about WWW can be accessed through telnet or ftp at "info.cern.ch".)

In the Internet's standards-development arm, the Internet Engineering Steering Group (IESG) has started a special directorate, the Internet Protocol Next Generation (IPNG). IPNG was formed to help the Internet keep up with its 15 percent-per-month growth rate. For one thing, the Internet is running out of possible host numbers and addresses; for another, Internet routers are having more and more trouble updating their tables as the number of networks on the Internet grows.

The Advanced Research Projects Agency (ARPA), Arlington, Va., has funded the Nimrod research project as part of IPNG. Nimrod investigators will look into new routing and addressing algorithms that, according to Noel Chiappa, a member of the Internet Engineering Task Force (IETF), will "create roadmaps for Internet routers to use and augment the 32-bit network addresses into variable-length network addresses." Nimrod is the latest of several ongoing and competing IPNG research efforts.

The Internet Society (ISOC) took on the job of promulgating Internet standards in connection with the work of the IETF. Its newsletter has become the official place in

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which to publish Internet standards.

In the private sector, two consortia were formed. One, the National Information Infrastructure Testbed (NIIT), consists of eight companies—AT&T, Digital Equipment, Ellery Systems, Hewlett-Packard, Network Systems, Novell, Sun Microsystems, and Synoptics—as well as Ohio and Oregon state universities, the universities of California-Berkeley and New Hampshire, the Smithsonian Astrophysical Observatory, and the Sandia National Laboratory. NIIT is intended to provide a nationwide high-performance testbed integrating distributed computing with advanced communications.

The Cross Industry Working Team (XIWT), made up of more than 25 computer and communications companies, was formed to promote a National Information Infrastructure (NII) through fostering the development and application of technologies crossing traditional industry boundaries. XIWT is focused on the technical issues surrounding the NII.

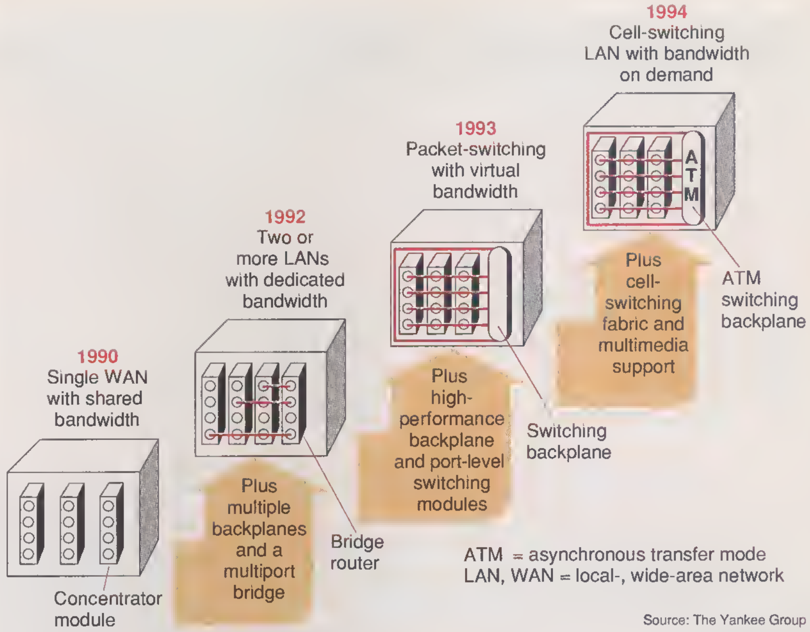
Another new consortium—the Telecommunications Policy Roundtable, a coalition of 60 nonprofit, consumer, labor, and civil rights groups formed to represent the public interest in the coming national data superhighway—is more concerned with policy than with technology. Policy, in fact, often dictates technology.

INTERNATIONAL. The fate of the Internet has become inextricably entwined with these U.S. data superhighway initiatives, which will affect communications worldwide. As Jon Crowcroft, senior lecturer at University College, London, said, "The U.S. controls what we're doing." Still, plans are afoot to link the three main European research networks—the UK's Janet (Joint Academic Network), France's Renata, and Germany's Berkom. ATM is being used on all three.

Terry Curtis, professor of communications policy at California State University–Chico and adjunct research fellow at the East-West Center, University of Hawaii, Honolulu, said that Japan's Visual, Intelligent, and Personal project for interactive multimedia will "drive the use of broadband ISDN. The Japanese don't wait for demand. They have a 20-year-plan that anticipates B-ISDN. Singapore is installing fiber everywhere, getting way out ahead of demand, too." But, he pointed out, "everyone waits for the U.S. to work out the kinks" in any new communications technologies.

Crowcroft argued that the growth of the Internet may conflict with the proliferation of ATM. Internet researchers are currently at work on finding a way of providing for hundreds of thousands of hosts and ever-growing millions of users, as entire countries get Internet connections. Each host and user requires a unique network address.

ATM, with its virtual-circuit connection-oriented switched architecture, indirectly promises to provide globally unique network addresses receptive to all forms of network traffic—whether voice, data, or video. ATM



ATM seems fated to take over data communications, but the takeover will be gradual. The technology is so new that even manufacturing strategies must be worked out. As shown here, hub makers turned first to router vendors for hub manufacture, but because too much of a switching hub's cost wound up in the outsourced switching components, they have been forced to develop their own technology—either in-house or with a technology partner.

cells must flow into unique network addresses once an ATM call is set up.

"ATM purists want to make everything pure ATM," said Crowcroft, "making it the X.25 of the '90s! Others think IP [the Internet protocol] can run just fine over ATM, so they really don't need ATM. There could be a culture clash between the telephone service providers and the Internet, between IPNG and ATM." In 1994, collisions between these two network-addressing schemes will become more visible.

Further complicating matters of unique network addressing, Novell began offering a registry for IPX addresses, so users of the world's most popular network operating system could be guaranteed unique IPX network addresses—which are growing in importance as more and more LANs are interconnected and the probability of duplicate network addresses increases. In conjunction with a network service provider such as ATT, the Netware registry could become a third competing source of unique global network addresses.

In 1994 Novell might offer the IPX protocol to the Internet, effectively putting the protocol into the public domain by placing it under the supervision of the IETF. Moreover, as IP is ever more widely used, it might become so embedded in the worldwide networking community that attempts to graft pure ATM onto it will not take. Yet, as Simone said, "data and voice people are being forced together" to find a way to build a workable network mesh.

CONVERGENCE. Disparate technologies are also coming together through what is being called convergence technology. By mid-1993, this commingling of voice, data, video, cable, and everything else had inspired several hundred alliances, licensing agreements, stock swaps, and the like on the part of cable, computer, network, hardware, software, and online service companies.

The proposed merger between Bell Atlantic, Philadelphia, and Telecommunications Inc., Denver, Colo., was only the latest corporate move to indicate that data communications was of interest to Wall Street, and not just to technologists. While these agreements were generally targeted at the consumer market, the technologies they will spawn and depend on (such as ATM) will certainly have a broad impact on data communications.

"There's a difference between simple cohabitation—carrying audio, video, and data on the same cable—and convergence, bringing the three together as part of a multimedia application," said BBN's Chapin. "Convergence is more creative, but different modalities, multiple points of entry are needed, because, for example, video is inherently analog, text inherently digital."

Set-top boxes are part of the convergence trend. These are consumer devices that allow television sets to take interactive advantage of the voice, data, and video that will be pouring into them. Startup 3DO Co., Redwood City, Calif., has already announced such a product. Other companies and alliances announcing similar products involve Microsoft, General Instrument, and Intel; Hewlett-Packard; Scientific Atlanta, Motorola, and Kaleida Laboratories; and TCI and ATT.

Personal digital assistants (PDAs)—hand-

held devices that perform a variety of tasks, such as receiving electronic mail and wireless communications—were also introduced last year, straddling the line between convergence technologies and mobile communications. "With PDAs, we'll get to see in the next year [1994] if they're useful or not," said California State's Terry Curtis. But Tom Halfhill, senior editor for *Byte* magazine, said that prediction is shortsighted, and that it will take 10 years for the technology to mature enough to meet all its expectations. Still, Curtis said, "PDAs might work like cellular phones in developing countries, providing wireless communications." The Newton MessagePad from Apple Computer Inc., Cupertino, Calif.; the ATT EO Personal Communicator; and the Personal Digital Assistant (née Zoomer) Z-PDA/Casio Z-7000 from Tandy Corp., Fort Worth, Texas, are the first manifestations of technologies that will be more common in 1994.

General Magic Inc., Mountain View, Calif.—a start-up spun out of Apple's Advanced Technology Group with partners ATT; Motorola; Mead Data Central, Dayton, Ohio; Sony, Tokyo; Philips, Eindhoven, the Netherlands; and Matsushita, Osaka, Japan—announced its Telescript and Magic Cap (Communications Application Platform) development tools. Magic Cap, a communications platform designed to create consumer communications applications, functions both as an operating system and as a user interface; Telescript is a communications language that works with intelligent software agents operating within devices attached to networks and PDAs, or within networks themselves. Magic Cap integrates Telescript, but Telescript does not require Magic Cap. General Magic says it will be rolling out actual products using Magic Cap and Telescript in early 1994.

WIRELESS. PDAs point up the growing trend toward wireless communications, a market that consultant Ira Brodsky, president of Datacomm Research Co., Wilmette, Ill., said will grow to $500 million by 1998. Krick said that wireless technology should "become more mainstream in 1994, attaining speeds for data transmission of 1–2 Mb/s."

SALWEN: Cooperation and compromise are key to realizing ATM's promise

VIEWPOINT

Few of us could have imagined 10 years ago that a 20-million-instruction-per-second machine with 16 megabytes of core memory would ever be viewed as a commodity to be used on our desks or cradled in our laps. Next in line to be explored and conquered is the multimegabit-per-second frontier. As with the megabyte-memory and million-instruction-per-second phenomena, it is difficult to predict how this gigantic communications capability will be used 10 years from now.

Industry analysts tell us that voice traffic will probably continue to dominate the telecommunications marketplace until the end of the decade. Facsimile, video-on-demand, and other services will occupy larger and larger shares of the total available bandwidth as we approach the year 2000. By that time, the method of choice for carrying these services will be asynchronous transfer mode (ATM).

Between now and then, ATM is expected to be the fastest-growing communications technique. At present, voice holds sway over the public-switched network. But ATM will be carrying some of this traffic toward the end of the decade, along with some data and video. Six years from now, ATM will consume almost as much network bandwidth as ordinary voice services.

From the beginning, ATM was intended to accommodate mixed media. Successful implementation will require data communications architects to work closely with voice architects to ensure that the technology fulfills its promise.

Cell size was the first ATM parameter to be defined through cooperation between data and voice people. The data people, concerned about the processing overhead required by cell headers, wanted very large cells. The voice people wanted small cells because they minimize latency. Small cells also simplify switch design and echo-suppressor implementation. The compromise: a 53-byte ATM cell (a 5-byte header and a 48-byte payload).

The data people are not totally happy with the relative inefficiencies of using small cells; given a free hand, they would have preferred 53-kilobyte cells. The voice people are not totally happy with the latency and switching-cost implications of 53-byte cells; they would have preferred 16 bytes. But a good compromise usually leaves both parties feeling a little uncomfortable. The 53-byte ATM cell is probably a good compromise—and just the first of many that will be made before ATM's design matures.

We need to define other ATM techniques and algorithms for sharing multi-megabit bandwidth among voice, data, and video. Many of our colleagues from the voice world have spent their careers studying speech characteristics to optimize telecommunications or security. As a consequence, much is known about the statistics of voice traffic. The same cannot be said of data.

'ATM will be compelled to compromise its intrinsic elegance in order to work with existing networks and provide a reasonable migration path'

We often hear data communications characterized as "bursty." We need to know what that really means, for there are no decades-long studies of the peculiarities of data traffic. Many more statistical characterizations of data communications will be needed to optimize the way data, voice, and video are combined on ATM.

Similarly, much of the work on video codecs has been based on the technologies available in the hitherto stable world of the public switched telephone network. Research on video codecs has assumed channels with constant bit rates because until now that was the only kind available. Part of the attraction of services such as ATM, though, is their ability to provide variable–bit-rate channels capable of adapting to their video information content. Again, much work is needed to determine the optimal utilization of ATM.

Managing multiple megabits on ATM will not be an easy task, and much must be learned in a rather short time. We will need new monitors, testers, and other tools to collect the statistical characteristics from which new models can be created. Such data will help us develop congestion-control algorithms that take into account the differing latency requirements of voice, data, and video. More important, our newly acquired ATM test data will assist in the development of fault detection, isolation, and work-arounds optimized for ATM.

Work in the ATM Forum—the informal industry standards organization—has highlighted the differences between the approaches to network management of telephony implementers and local-area network (LAN) implementers. LAN implementers are more concerned than ever with network reliability and availability as their products assume mission-critical roles.

All the same, their level of concern cannot yet compare with the traditions of the telephone companies, which have been emphasizing reliability and availability for decades. Network management for public telecommunications need not be identical to that used in private networks, but the two must play smoothly together.

As originally conceived, ATM is elegant in its operation and utility. Nonetheless, the exigencies of the real world usually chip away at elegant design and, in fact, affect even ATM's deployment. If ATM could suddenly replace all existing networking gear, there would be no need for routers, hubs, or switches. But most likely, network managers will phase in ATM slowly, while replacing currently installed networks. The intrinsic elegance of ATM will be compromised so that it can work with existing networks and provide a reasonable migration path.

Current networking technology is quite

In addition to its obvious uses in mobile data communications and disaster recovery, wireless has other applications for which it is uniquely suited. Among them is fulfilling a variety of temporary requirements—unplanned expansions of existing networks and providing facilities for short-term training programs and for communications at conventions and trade shows, to name but three. It is also useful when people (and their terminals) must be relocated frequently. And it is an attractive alternative when cabling is difficult—for instance, when construction cannot be undertaken because of, say, asbestos problems or historic landmark designation.

As for specific developments in wireless communications, version 1.0 of the Cellular Digital Packet Data (CDPD) specification was released in July. Bell Atlantic; McCaw Cellular Communications Corp., Redmond, Wash.; and Ameritech Inc., Chicago, offered to make the service available. The Portable Computer and Communications Association (PCCA), Brookdale, Calif., has developed an AT command set for wireless modems usable across all packet- and circuit-switched networks.

The Federal Communications Commission (FCC) will this year be auctioning off portions of the microwave part of the spectrum for Personal Communications Services (PCS), which will use spread spectrum technology for ever more ubiquitous—and personal—communications. Spread spectrum allows multiple senders and receivers to share the same portion of the spectrum by having each sender encode its transmission in a unique way decipherable by only its intended receiver. The outcome of the FCC auction will also affect the fates of the competing satellite personal communications services, deciding whether Motorola's Iridium; Globalstar, from Loral/Qualcomm, San Diego, Calif.; and others will be able to create a worldwide cellular network that is based on satellites.

In 1993, there were also terrestrial approaches to this dream of ubiquitous computing. Researchers at Xerox Palo Alto Research Center studied intelligent agents that track and hand off functions among devices of increasing intelligence. These agents, based on a campus, notice user locations by receiving information from a badge, provide basic functions to a PDA, exchange general computer functions and data with notebook-sized devices, and communicate with a liveboard. Private microcells in homes and offices would oversee this model of mobile computing, handing off to public cell-communications providers when users are neither at home nor at work. ATM has been suggested as the technology to handle the public portion of this intelligent-agent networking scheme.

BITS AND PIECES. Encryption was also in the news, with the U.S. government proposing the Clipper/Skipjack public-key encryption algorithm. Commercial versions of the Pretty Good Privacy (PGP) public-key encryption were put on the market by the Via-Crypt division of Lemcom Systems Inc., Phoenix, and Austin Code Works, Austin, Texas. Both Clipper and the commercial encryption products met a flurry of legal and regulatory actions and protests, retarding their deployment.

IEEE P1394, or Serial Bus—a new standard fostered by IBM and Apple—was designed as a general-purpose interface replacing a variety of input/output types, such as RS-232-C, RS-422, and SCSI. Currently rated at 100 Mb/s, it is said to be able to scale up to 400 Mb/s. Fibre Channel, a switched channel connection alternative to the high-performance parallel interface (HIPPI) and other high-speed channel attachments, operates at speeds up to 1 Gb/s, and, as BBN's Chapin noted, "gets data off devices very efficiently."

The first modems said to conform to the CCITT V.fast 28.8-kb/s standard were announced, and some vendors also announced products complying with V.32turbo, a proprietary specification for 19.2-kb/s communications. ◆

Local-area network architectures

Characteristics	FDDI	CDDI	Switching hub	100-Mb/s Ethernet	ATM (a)
Channel occupancy	Shared	Shared	Shared/ dedicated	Shared	Switched
Maturity of technology	Young adult	Preteen	Preteen	Prenatal	Infant
Support for virtual LANs	No	No	Limited	No	Yes
Seamless interface (speeds and protocols) to public network	No	No	No	No	Yes
Scalability	Difficult	Difficult	Somewhat difficult	Difficult	Yes
Cost per NIC, 1993	$2000	$1000	N.A.	N.A.	$4000
" " " , 1996	$350	$250–$350	N.A.	$200–$250	$500 (for 155 Mb/s)
Cost per hub port, 1993	$1K–$3K	$1.5K–$2K	$750	N.A.	$5K
" " " " , 1996	$700	$500	$300	$300	$700–$900
Media requirement	Fiber	UTP	N.A.	UTP	Fiber or UTP (a)
Multiple LAN speeds supported	No	No	N.A.	No	Yes
Modification to existing wiring	Yes	No	No	No	No (a)

Source: The Yankee Group

CDDI, FDDI = cable-, fiber-distributed data interface; LAN = local-area network; N.A. = not applicable; NIC = network interface controller. (a) Asynchronous transfer mode (ATM) will eventually support a variety of speeds and media. However, current standards and vendor development are limited to multimode fiber. Unshielded twisted pair (UTP) standards and products are expected before the end of 1994.

different from that of ATM. Packet communications are generally based on connectionless datagrams; ATM is basically connection-oriented. An adaptation layer has been defined to take care of the more obvious differences between the two. But many other complexities arise when old and new technologies must work together.

For example, the ATM Forum and the Internet Engineering Task Force (IETF) are working on standards to relate E.164 telephony addresses to 48-bit LAN addresses. Given such a correspondence, it will be possible to deal with connectionless multicast traffic in the connection-oriented ATM environment and to coordinate ATM call-setup with current address-resolution procedures. A robust solution to these and other problems is not trivial, because the networks in which they must work will be used by millions of people.

Many similar though as yet unknown problems and pleasures complicate ATM's deployment. But voice and data experts are working steadily on the compromises that will bring civility and productivity to the multimegabit-per-second frontier—one that promises to be as exciting and rewarding as the million-instruction-per-second and memory frontiers. If history is an accurate teacher, the next few years will see a number of trial applications come and go before the real long-term uses of this new and powerful technology are revealed to us.

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The author wishes to thank Dan Upp of TranSwitch Corp., Shelton, Conn., and Steve Willis of Wellfleet Communications Inc., Bedford, Mass., for their interesting and useful ideas.

Consumer electronics

It's war! And to the victor goes control of the home television receiver. Never exactly a peaceful industry, consumer electronics is now in the midst of several battles. Some are close to resolution, some are in heated contention, and for others the opponents are just choosing up sides.

PEACE PACT. Perhaps the most significant fight is about to be settled. It's over the selection of a standard for the next TV generation, high-definition television (HDTV).

This choice will determine television's capabilities for decades. In 1979 Japan transmitted its first test of analog HDTV by satellite. European countries developed another analog system for satellite broadcasts, HD-MAC, hoping to prevent the Japanese consumer electronics powerhouses from swamping the continent's TV industry.

But this race was not to the swift. In the late 1980s the U.S. Federal Communications Commission's (FCC's) Advisory Committee on Advanced Television Service stepped in and began evaluating more than 20 proposed HDTV systems. In 1990 General Instrument Corp., Chicago, shocked the industry by demonstrating that it could transmit TV signals completely digitally and, to top things off, disclosed a proposal for digital HDTV. The technology had not been expected to appear for years.

Digital transmission is preferred to analog for several reasons. It can be implemented at lower power levels, interfering less with existing National Television System Committee (NTSC) signals, and its quality is also constant throughout a given service area. Digital TV receivers could also be compatible with a wide variety of computer and telecommunications services. Most of General Instrument's competitors hurried to develop digital systems of their own, and entered them in the standards competition.

A digital HDTV standard is expected in 1995. Last year the pack of competitors, in all five systems proposed by four groups, completed extensive testing. The only analog proposal, NarrowMUSE from Nippon Hoso Kyokai (NHK), Tokyo, was rejected because of marked interference problems. The four digital proposals came from General Instrument and the Massachusetts Institute of Technology (with two system proposals); AT&T and Zenith Electronics; and the Advanced Television Research Consortium, consisting of North American Philips, Thomson Consumer Electronics, David Sarnoff Research Center, Compression Laboratories, and NBC.

Tekla S. Perry Senior Editor

Instead of selecting one of these, the FCC Advisory Committee judged that the systems had few differences and a number of shortcomings, in particular interference with NTSC broadcast signals. It therefore recommended retesting unless the groups formed a "grand alliance" and proposed a single hybrid system.

The Grand Alliance came together on May 24. In October it announced technical decisions on four key subsystem technologies: it had chosen a packetized system for data transport, Dolby AC-3 audio technology for sound, the MPEG-2 video compression technology, and a set of scanning formats.

MPEG 2 is one of a group of standards being developed by the Moving Picture Experts Group to provide a coded representation of audio and video signals. The MPEG standards outline a structure for data blocks, as well as the allocation of bits within those blocks, to different characteristics of the video signal, like chrominance and luminance. MPEG's compression scheme relies on the analysis of images, compressing them by eliminating redundancies and coding only the changes between frames rather than entire new pictures for every frame.

MPEG 1, which adapts digital video to the CD-ROM format with a data rate up to 1.5 Mb/s, was published in 1992.

HIGHLIGHTS

- **HDTV rivals form Grand Alliance**
- **Plans for smart TV decoders proliferate**
- **Digital satellite broadcasts begin**
- **Personal digital assistants need more work**

MPEG 2 is a digital video standard encoded for much higher bandwidths than those of CD-ROMs—to 15 Mb/s and beyond. It is therefore appropriate for transmitting video over cable, fiber, satellite, or over-the-air terrestrial broadcasting. The draft standard, to be released last November, should be published late this year. (MPEG 3 was initially intended to be the MPEG standard for high-definition television, but its functions have been merged into MPEG 2.)

Late last year the MPEG group began work on MPEG 4, for very-low-bit-rate coding of audio and images, meant to be used across wireless mobile computer networks. The group is currently defining the problem and has much work yet to do. A draft standard is expected to be completed in 1997.

The set of scanning formats chosen included 24, 30, or 60 frames progressively scanned at 720 active lines of resolution, 24 or 30 frames progressively scanned and 60 interlaced fields both at 1080 lines of resolution. These formats are intended to encourage an evolution toward a progressive scan rate of 60 frames at 1080 active lines.

The choice of scanning formats was a concern to both computer and consumer electronics manufacturers. The computer industry prefers progressive scanning, in which the electron gun hits every row of phosphor dots in sequence, to lessen the display flicker. Many TV manufacturers and broadcasters favor interlaced scanning, in which the electron gun hits every other row of dots and then goes back to trace the missing rows, because, at a given bandwidth, it allows higher resolution at comparable data rates.

The alliance has yet to settle on a transmission technology. This is no small challenge, for the chosen system must deliver about 20 megabits per second in a 6-MHz channel amid echo, interference, and noise. Two basic modulation systems are in contention. "The bake-off [a set of tests of the systems] will begin in January," said Paul Misener, an aide to the advisory committee. The committee's technical subgroup plans to meet in February to consider the test results.

Misener told *IEEE Spectrum* that he expects the alliance to complete a system prototype this fall, when it would undergo a thorough series of tests; the committee, he said, may be able to make a final recommendation to the FCC by early 1995. After field testing and opportunities for public comment, the FCC could make its decision soon, and HDTV sets manufactured under the new standard could reach the market in 1996.

Whatever HDTV system the FCC approves could become the basis for a world standard. Despite Japan's early start in HDTV, only some 20 000 of the analog HiVision TV sets have been sold. Japan is planning eventually to introduce some form of digital HDTV, possibly when it launches its next-generation satellite, in 2007; no specific dates have been announced, however.

Meanwhile, the European Union (formerly Community) has accepted the death of HD-MAC and canceled a plan to provide $1 bil-

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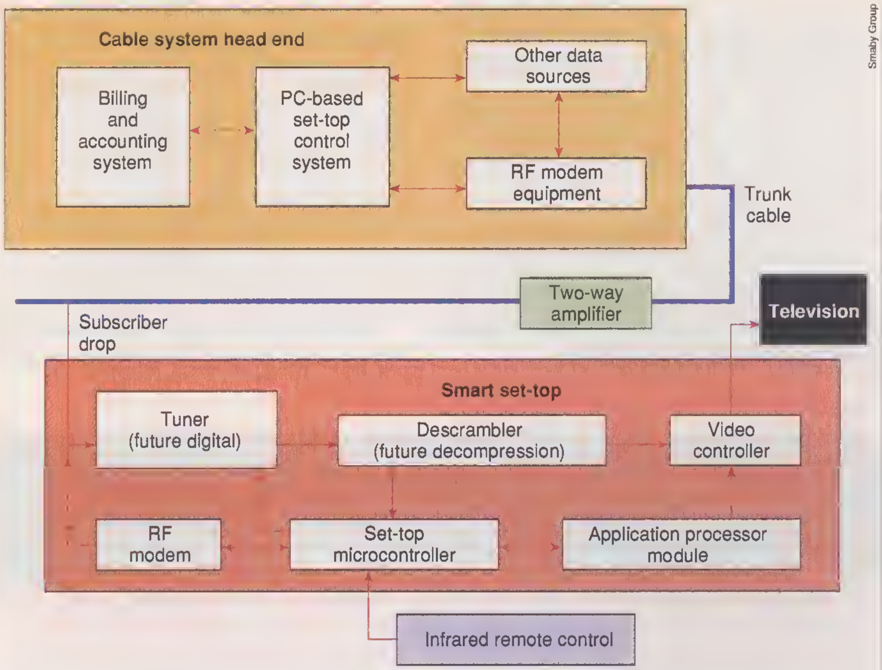


Today's set-top boxes (also called cable decoders) have minimal electronics; but to be capable of decoding interactive applications, the smart set-top box will have to be much more sophisticated. It will probably be modular, for easy upgrading for additional applications. This diagram shows one way of organizing such a system. To save money on initial installation, the decompression capability is engineered as one add-on module, while the application processor module can be augmented by ever more powerful modules as new systems roll out.

lion to HD-MAC programming. Philips Electronics NV, Eindhoven, the Netherlands, has also canceled its plans to begin producing HD-MAC TV sets this year. A group of 85 electronics companies, broadcasters, and satellite operators formed the Digital Video Broadcasting Project to develop digital technology for the European market.

Only the Scandinavian countries appear likely to go off on their own in selecting an HDTV format. Broadcasters and manufacturers from Sweden, Denmark, Finland, and Norway are jointly developing the digital HD-Divine system, scheduled for completion in 1995, with a demonstration transmission from the 1994 Winter Olympics. HD-Divine is expected to include the MPEG-2 standard for video coding.

A DIGITAL VCR. Not surprisingly, the development of a digital videocassette recorder (VCR) has also begun. In hopes of preventing the consumer confusion that would result from competing standards, Philips, Matsushita Electric Industrial, Sony, and the Victor Co. of Japan (JVC) have joined Hitachi, Mitsubishi, Sanyo Electric, Sharp Electronics, Thomson, and Toshiba to set up a worldwide digital VCR standard compatible with digital HDTV.

The expectation is that the digital VCR will cope with existing television formats, as well as HDTV, recording each singly in a single baseband format. In addition, it is to be able to record a bit stream, so that it could reproduce MPEG-2 material through a TV set's decoder. The consortium currently hopes the first digital VCRs will reach the market in 1997.

Satellite broadcasting is also going digital. DirecTv Inc., El Segundo, Calif., a unit of GM Hughes Electronics, in cooperation with France's Thomson CSF and others, is this year initiating a digital NTSC direct broadcast satellite system. The first of two broadcast satellites was to be launched this past December; the second will go into orbit in the middle of this year.

Given success with the first launch, transmission will begin this April. On the receiving end, these high-powered satellites will require only 45-cm dishes—the smallest so far—compared with the 1–3-meter dishes of current satellite receivers. The receiver packages—the dish, a decoder box, and a remote control—will sell for around $700. Hughes will launch DirecTV, initially with 50 channels, rising to 150 when the second satellite is launched, and it will sell any surplus broadcast capacity to others.

Meanwhile, Primestar Partners, Bala Cynwyd, Pa., which currently sends analog satellite programming to rural subscribers across the United States, will be switching to digital NTSC broadcasts in the first quarter of this year, company president John Cusick told *Spectrum*. By mid-year, Primestar expects to be sending 70 digital channels to its 0.9-meter dishes.

Both satellite systems will use the MPEG-2 digital video compression standard.

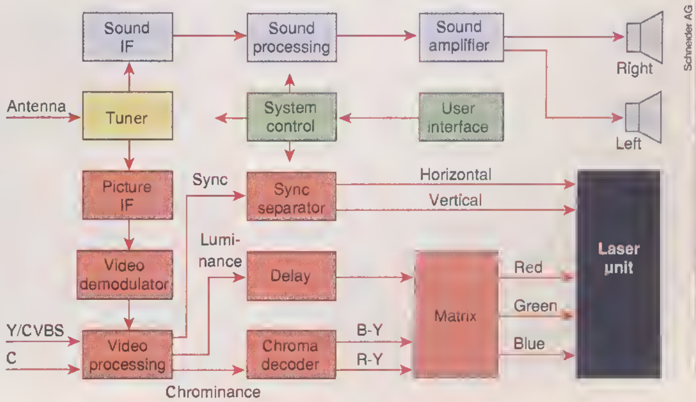
CHOOSING ALLIES. Meanwhile, the companies that operate broadcast and cable networks are planning to bring interactive TV into the home one way or another. First to be implemented: interactive technologies that combine cable, over-the-air, or satellite TV transmissions with radio broadcast transmissions.

In 1992 the FCC allocated the 218–219-MHz frequencies in the VHF band for use with interactive video and data services. In September, the commission issued by lottery two licenses, each for nine major cities, out of a planned group of 734 service areas in the United States. Winners of the licenses are to create an interactive network by building systems similar to today's cellular networks.

Three companies have emerged to provide interactive technology to the licensees: Interactive Network, Mountain View, Calif.; Radio Telecom & Technology, Riverside, Calif.; and Eon (formerly TV Answer), Reston, Va. Services could include games, on-screen TV listings, automated VCR programming, home shopping, and home financial management facilities, as well as educational programming.

Interactive television that operates using only cable or telephone networks is also seen as arriving soon. The key—moving to digital

While most attention has been fixed on new TV broadcast systems, Schneider AG, Turkheim, Germany, has developed a display that uses a laser to produce the picture. Today's cathode-ray tubes use an electron gun to activate red, green, and blue phosphor dots to create a picture; in the proposed laser system the laser itself produces the colors of the picture, which can be displayed on any front or rear projection surface in any size. The company indicated that laser TV would be particularly suitable for displaying large high-definition pictures. Schneider is also promoting the environmental benefits of laser TV, in that it should require only 20 percent of the energy used by conventional picture tubes and also be easier to dispose of, since it lacks the bulky tube with potentially toxic screen coatings.



transmission from the current analog format—will require today's analog set-top box to yield place to a digital smart set-top.

Current cable boxes have minimal electronics: analog tuners, a microcontroller, about 128 bytes of RAM, a few kilobytes of ROM, and a low-speed modem that is told which channels to descramble. The next generation, predicts David Frankel, director of technology for the Smaby Group, Minneapolis, will add a second microcontroller and more memory to run electronic program guides; they will also have a port for a digital decompression processor and another for a processor and memory to run interactive applications [see top figure, previous page].

Such smart set-tops are being designed, and they will start to be sold next year. According to Craig Tanner, vice president for advanced television projects at Cable Television Laboratories, Boulder, Colo., cable operators are already committed to buying $2.6 million worth. General Instrument's facility in Hatboro, Pa., for example, expects to begin shipping a smart set-top in November.

At the least, digital transmission will mean more channels, theoretically allowing a cable operator to transmit simultaneously 10 VCR-quality programs (or up to six NTSC-quality programs) for every one of today's analog channels. Megachannel systems will enable something close to video on demand, Frankel said, with a movie restarting every 15 minutes. (True video on demand allows viewers to order from extensive tape libraries, to fast-forward, to pause, and so forth, just as if they were using a VCR.) The first megachannel systems will be tested this year and may start to be installed outside the test markets. They will require more expensive computer hardware on both ends of the cable line, but no major infrastructure changes.

More complex applications, which let users play games, order merchandise, obtain coupons on request from attached printers, and engage in other interactive pursuits will require infrastructure upgrades if they are to be efficiently implemented—what Time Warner Cable, Stamford, Conn., calls fiber to the neighborhood, said Walter Ciciora, the company's vice president of technology. The upgrades are under way. Ciciora said Time Warner expects to have 6 million of its 7.1 million subscribers on fiber-to-the-neighborhood networks within four years.

Numerous experimental networks are being put into place by Time Warner and others, and interactive applications will be tested throughout the year in Orlando, Fla.; Castro Valley, Calif.; Chicago; Denver, Colo.; Omaha, Neb.; and perhaps other places.

While no one is entirely sure which interactive services consumers will use—and pay for—both network providers and hardware manufacturers see a gold rush coming and are creating teams to fight for a piece of the profits. A typical team might include a network provider, a software provider, and a computer hardware company. So far, the teams include the following:

- Time Warner, Silicon Graphics, Scientific Atlanta, Toshiba, and Hewlett-Packard.
- Kaleida, Motorola, and Scientific Atlanta.
- TCI, Sega, and Time Warner.
- Microsoft, Intel, and General Instrument.
- Philips Electronics and GTE Vantage.
- U.S. West, the 3DO Co., AT&T, and Digital Equipment.
- Novell and Geoworks.

It will be several years before smart set-tops are as ubiquitous as today's cable converters. In the meantime, for interactive TV applications, the technology of choice is the compact-disc ROM (CD ROM).

Again, developers of this interactive technology did not band together to select a standard, choosing instead to fight it out in the marketplace. And the battle has begun. A gaggle of interactive video systems have been introduced or announced [see table, below], using 16-, 32-, and 64-bit processors; custom graphics chips, animation chips, and sound chips; playing audio CDs and video-game cartridges; and displaying photographs. Some will survive; most will go the way of the Betamax.

To software developers, which technology wins hardly matters. "We just hope one of

Interactive video for the home

	Medium			
	Cartridges	CD capability, standard and proprietary	Laser videodiscs (analog)	Cable ready?
Nintendo Entertainment System (Nintendo Co., Kyoto, Japan)	Yes	None	No	Yes
Super Nintendo Entertainment System (Nintendo Co.)	Yes	None	No	Yes
Genesis (Sega Enterprises Ltd., Tokyo)	Yes	None	No	No
Genesis with Sega CD	Yes	CD ROM Audio	—	Yes
Photo CD (Eastman Kodak Co., Rochester, N.Y.)	No	CD audio and photo	No	No
CD-I (Philips Electronics NV, Eindhoven, the Netherlands)	No	CD-I Audio Photo Video* ($249)	Yes	Yes
Video Information System (Tandy Corp., Fort Worth, Texas)	No	CD interactive Audio	No	No
LaserActive (Pioneer Electronics, Tokyo; Sega Enterprises, NEC Home Electronics)	Yes	CD ROM ($600 attachment) Audio Video	Yes	No
Jaguar (Atari Corp., Sunnyvale, Calif.)	Yes	CD ROM ($200 attachment due late 1994) Audio Photo & Video	No	No
3DO Interactive Multiplayer (Matsushita Electric Industrial Co., Osaka, Japan)	No	CD ROM Audio Photo & Video	—	No
AmigaCD32 (Commodore International Ltd., West Chester, Pa.)	No	CD ROM Audio planned Video* ($250)	—	Yes
Project Reality (Nintendo Co. and Silicon Graphics Inc., Mountain View, Calif.)	—	—	—	—
No name yet (Sony Computer Entertainment Inc., Tokyo)	—	CD ROM	—	—

*Requires MPEG add-on cartridge. — = not applicable or not supplied ASIC = application-specific integrated circuit;

them wins, and soon," Rob Fulop, creative director of PF Magic, a San Francisco–based interactive video producer, told *Spectrum*.

These systems may even play feature films. Philips, Matsushita, JVC, and Sony last year set a standard, compatible with the current TV standards of different countries, for recording VHS-quality video material on CDs. The system relies on the MPEG-1 format for video encoding; decoders should be available this year for audio CD players, CD-ROM–based entertainment media, and computers.

While CD movies are expected to be a powerful selling point for interactive CD-based systems, today's disc can store only 74 minutes of video, and most feature films are longer. Higher densities are possible with current technology, however. Today's systems use lasers with a wavelength of 680 nanometers; high-density systems would move to a 570-nm wavelength, which, with reduced track spacing and pit size, can store four times as much information as on existing CDs. That would be enough for 4 hours of video at the MPEG-1 transfer rate, or 2 hours with a doubled sampling rate using MPEG 2. They would also permit the use of a 20-bit audio-sampling rate (the current CD standard uses 16-bit sampling). Denon America Inc., Parsippany, N.J., demonstrated a quad-density prototype CD last year, and Philips is said to be preparing a draft standard for high-density compact discs. Further in the future, when blue lasers become commercially available, are even higher densities. A prototype blue-laser system was demonstrated by Nimbus, Monmouth, Gwent, UK, last year.

Even within today's CD standards, CD audio has been improving as manufacturers address the audiophiles' lament over the lost subtleties of analog recordings. Several com-

Hardware						Marketing	
Processor (CPU clock)	Custom coprocessors	RAM: main, video, audio (cycle time)	Resolution	Animation speed, million pixels/s	Colors displayed simultaneously	Price	No. of software titles available by 1/1/94 (first shipped)
8-bit (2 MHz)	—	2 kb plus 2 kb video	256 × 240	—	16	US $60–$80	687 (10/85)
16-bit 65C816 (3.58, 2.68, and 1.79 MHz)	8-bit sound plus 16-bit graphics; plus in some cartridges Super FX chip is RISC chip for graphics acceleration	128 kb plus 64 kb video (279 ns)	512 × 448	1	32 768	$90–$150	266 (8/91)
16-bit MC68000, Z80 (8 MHz)	Graphics PV	512 kb plus 512 kb video plus 64 kb audio (525 ns)	320 × 224, 320 × 448	1	64	$100	>300 (fall 1988)
MC68000 (12.5 MHz)	Graphics	—	320 × 224, 320 × 448	1	64	$100 + $230	77 (11/92)
—	—	—	192 × 128 to 6144 × 4096	—	16.7 million	≥$199	Self-generated (from personal photos) (6/92)
16-bit Motorola 68070 (15 MHz)	—	1 MB plus 1.5 Mb in add-on digital video cartridge (varies)	384 × 768	1.4	16 million	$499–$599	125 (10/91)
—	—	—	320 × 200, 320 × 400, 640 × 200, 640 × 400	—	16 million	$399	70 (11/92)
16-bit with Sega CD ROM add-on; 8-bit with NEC CD-ROM add-on	—	—	—	—	—	$970	400 cartridge titles, plus 10 interactive titles on 12-inch laser discs (8/93)
64-bit custom processor (26.6 MHz)	2 ICs containing 4 processors (for DSP, graphics, objects, and blitter/shader)	2 MB plus 4 kb of graphics processor cache RAM plus 8 kb of DSP cache RAM (80 ns)	160 x 100 to 720 x 592 with 32-bit color	850	16.7 million	$250	4 (11/93)
32-bit RISC CPU (12.5 MHz)	3 (2 for graphics, 1 for DSP)	2 MB plus 1 MB video (80 ns)	640 × 480	64	16.7 million	$700	20 expected (10/93)
Motorola 68EC020—32-bit (14 MHz)	4 (for video, graphics, and sound)	2 MB, plus RAM on custom video and audio chips (120 ns)	320 × 200 to 1280 × 400	7	256 000	$399	50–100 (9/93)
64-bit MIPS RISC microprocessor (100 MHz)	Silicon Graphics graphics coprocessor and ASICs	—	Compatible w. future HDTV standards	—	—	Target: $250	— (late 1995)
—	—	—	—	—	—	—	— (end of 1994)

CD ROM = compact-disc read-only memory; CPU = central processing unit; DSP = digital signal processing; RAM = random-access memory; RISC = reduced-instruction-set computing.

AOKI: Digitalization and integration portend a change in life-style

VIEWPOINT

In recent years, the consumer electronics industry has been in a slump. At fault is not only the global economic recession but also the lack of attractive new products to drive the market, as the color television set, videocassette recorder, compact disc player, and camcorder did in the past.

Now, however, another boom is about to begin, one that may lead to life-styles marked by a different division between what we now call work and leisure. The foundation for this revitalization is being laid by the industrywide move from analog to digital signals and by the integration of audio, video, and computer-based equipment.

Audio digitalization started with the introduction of the compact disc (CD) in 1982, soon followed by digital audio tape. These technologies, together with the recent introduction of the mini-disc and the digital compact cassette, established digital audio in the consumer market.

Today, digitalization is being pursued aggressively in consumer video. A key industry announcement during the year was the establishment of the High Definition Digital VCR Conference by 10 companies, led by Matsushita, Philips, Sony, and Thomson. The conference, which is open to industry participation, is to define a set of high-definition specifications for consumer digital-VCR (D-VCR) standards. These standards are to be designed around a basic specification, in the hope that this will become a worldwide format. If that happens, manufacturers will be able to make videocassette recorders (VCRs) using the D-VCR standard for all analog and digital high-definition formats, as well as for the current PAL, NTSC, and Secam formats.

An important part of the move to digital products is the effort under way by the Moving Picture Experts Group (MPEG) to standardize the bit-reduction algorithm for digital audio and video signals. The current MPEG-1 standard is suitable for bit rates of up to about 1.5 Mb/s. A second standard, MPEG 2, is being developed for coding much higher frequency signals, including that of high-definition TV (HDTV). (Contrariwise, analog HDTV is gaining popularity in Japan, where less expensive HDTV sets have been introduced and HiVision Laser Discs and the W-VHS VCR have been announced—the discs by Matsushita, Sanyo, Sony, and others, and the VCR, which can record high-definition signals with close to high-definition quality, by Victor Co. of Japan, or JVC.)

A significant aspect of the digitizing trend is that all types of data, whether audio, video, or computer-based, can be treated on the same platform. This integration will be central to a highly diverse next generation of consumer electronic products, which in turn will generate new markets. These integrated products need not combine functions from all these areas; even effectively utilizing two or more will give birth to products with exciting possibilities.

'So we will go through a chicken-and-egg period with many new ideas being offered to the consumer'

Consider the personal intelligent communicator, based on technologies from General Magic Inc., Mountain View, Calif., and promoted by an alliance of industry leaders: Apple Computer, AT&T, Matsushita, Motorola, Philips, and Sony. This product combines a personal terminal with communication devices like the digital cellular phone (now being launched in the United States and Europe), allowing users to keep in close touch with the office by linking up remotely with various information services. With these new devices, people will be able to communicate and gather information in powerful new ways.

Recent announcements include the Newton models from Apple and Sharp. The advanced communication facilities such models offer will open the door to the possibility of downloading music or even a movie into a hand-held system, thus moving these products into the area of personal entertainment.

The push toward integration will also merge what we now call a TV set with a PC into a single multimedia system equally useful at home and office. These sets will be configured in a variety of ways and with a range of capabilities. The main technology developments required here will be faster, low-cost, low-power large-scale ICs, as well as storage devices, high display resolution, and color liquid-crystal displays.

As the digitalizing and integrating trends of 1993 continue, the classical boundaries between the consumer electronics, computer, and communication industries will eventually fade. It is tempting to try to coin a term to classify these promising new products, for the word most used—"multimedia"—still has no one definition. In fact, it is still unclear what type of multimedia product the customer wants.

What is clear, though, is that these products could lead us to a completely new life-style. Of course, until they are available, this new life-style cannot develop; and until this life-style begins to develop, the types of products it requires remain uncertain. So we will go through a chicken-and-egg period with many new ideas being offered to the consumer. Only some will hit the mark and when they do, they will touch off a new generation of products that will make major changes in how we divide our work and leisure time.

Teruaki Aoki (M) is senior general manager of the Recording Media Products Group of Sony Corp., Tokyo, where he is responsible for all recording media business. He previously was head of Sony's R&D corporate planning group, where he had control of the corporate R&D budget, the promotion of new strategic initiatives, and the creation of new business areas. He has served on Sony's board of directors since 1989.

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panies, including Sony, Denon, and Pacific Microsonics, are using a dithering process to produce audio on a 16-bit system that for quality of sound compares well with a 20-bit sampling rate. This mathematical requantization, said Almon H. Clegg, a consultant to Denon, extends the dynamic range, lowers the noise floor, and reduces distortion.

DIGITALLY YOURS. Not all the technological action these days is in the TV room. A new category of consumer electronic devices made its debut last year: the personal digital assistant (PDA), or personal intelligent communicator (PIC), or generic personal digital device (PDD)—the industry seems unable to agree on a name. Whatever they are called, these hand-held computers without keyboards use a stylus and a touch-sensitive tablet for input, as well as PCMCIA cards for storage. They are designed to maintain an address book and a calendar, and can link the two. They also allow simple diagrams to be drawn and stored, as well as short notes to be written, and will search and sort stored data. With (or some without) an upgrade, they can send faxes, use electronic mail, and receive wireless pages.

The Newton got the most press in 1993. It was shipped first in August by Apple Computer Inc., Cupertino, Calif., as the MessagePad and by Sharp Electronics Corp., Osaka, Japan, as the ExpertPad. The $700 computer is based on an ARM 610 processor with a custom application-specific IC, 4 MB of ROM, and 640 kB of RAM. Casio Inc. and Tandy Corp. jointly introduced the $700 Zoomer PDA in October. Amstrad PLC, London, introduced the PenPad PDA600 ($500) in May. AT&T's entry in this category, at over $2000, including a wireless modem, was the EO Personal Communicator.

Other computer and consumer electronics companies are reportedly developing PDAs as well, including Sony and Compaq Computer Corp.

PDAs live or die on the strength of their handwriting recognition, and so far that technology has proved weak. Newton's errors were even the butt of a series of jokes in "Doonesbury." So while these devices may prove useful in later incarnations, the first generation representatives appear to be mere flashy gadgets, though third-party software may go far toward making them more useful. ◆

PCs and workstations

The long-anticipated union of PCs and workstations began in earnest last year, ushering in another era in computing. Each group ceded the central processor slot to the latest chips based on reduced-instruction-set computing (RISC): Alpha, MIPS, PA-RISC, PowerPC, and microSparc. Complex-instruction-set computing (CISC), meanwhile, is not dead, certainly not in notebook computers and microcontroller-based systems; but its future in the general-purpose computers of the next millennium is moot.

RISC is to be seen in all sorts of systems, from supercomputers to TV sets. This ubiquity has coincided on the operating system side with Windows NT's introduction and the increased standardization of Unix. The upshot is that in 1994 companies will need less time to deploy reliable networks based on the client-server architecture—one of last year's most popular phrases.

Like distributed client-server computing, multimedia and interactive video communications are new pillars on which modern businesses are now being built.

Traditional office equipment will tie in to computers easily this year, and companies will shift to operations that are fully integrated yet distributed throughout the enterprise. As standards for the electronic transmission of documents emerge, the less-paper, if not paperless, office will arrive.

HIGHLIGHTS

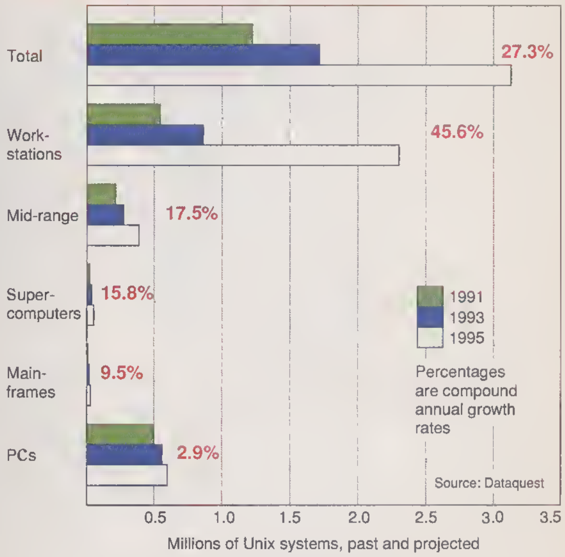
- **RISC-based computers invade CISC territory**
- **Multimedia systems mushroom**
- **Active-matrix screens get hyper**
- **Notebook can display in three dimensions**

MICROSOFT'S HARD DRIVE. It was not RISC alone that called CISC's viability into question; it was the latest version of Windows, which had been CISC's mainstay operating system (OS). Windows NT, the OS delivered last summer by Microsoft Corp., Redmond, Wash., gives greater freedom of hardware choices to users. Formerly, any who wanted a 32-bit environment for existing Windows and DOS applications had to depend on an underlying Intel architecture. With Windows NT running on most of the new RISC processors, those in the market for a new computer can finally focus purely on performance without worrying about hardware compatibility.

Despite what seem to be the obvious advantages of Windows NT, Microsoft spent 1993 fine-tuning the market's perception of its "New Technology." As of late 1992, it seemed that NT would be Microsoft's unifying OS, bringing DOS and Windows together for all time. Then, as NT's introduction drew nearer, the company said that the new product would not be a replacement for Windows 3.1 and DOS but, rather, an OS targeted at those early adopters who could make use of its unique attributes. Instead of displacing Windows 3.1, NT would move Microsoft into new territory. The company that got its OS start in cloning Unix for the PC would take on Unix itself.

According to *The Wall Street Journal*, the latest word on Windows NT—from no less a source than Microsoft chairman William Gates—has it that "The sales are above our expectations. The corporate acceptance is above our expectations. The software acceptance is above our expectations." However, he would not state what those expectations had been nor say what sales actually were. In mid-November, Paul Maritz, senior vice president of Microsoft's Systems Division, said that NT was undergoing evaluation at many sites and that over 200 000 units of the OS had been shipped. In contrast, the number of Unix shipments for all of 1993 was projected at 1.7 million by Dataquest Inc., Cupertino, Calif., which said that the amount spent on Unix has been growing at an average annual rate of about 20 percent since 1991. To further impede NT's growth, IBM is planning a late-year unveiling of its Workplace OS, based on a refined version of the MACH kernel developed by Carnegie Mellon University, Pittsburgh.

Past and future Unix unit sales



The Unix operating system is still unmatched for availability across the full range of computer platforms. Dataquest said compound annual growth is close to 30 percent.

Still, Microsoft's move into corporate computing will be relentless this year, as the company builds not only on NT but on its coming release of Window 4.0 and, more importantly, the Microsoft at Work OS blueprint. Unveiled in June, the Microsoft at Work OS will integrate office equipment into an enterprise-wide network. "Microsoft at Work is the catalyst that lets this market explode," claimed Eric Steenburgh, president and chief executive officer of office-equipment supplier Ricoh Corp., West Caldwell, N.J., a wholly owned subsidiary of Ricoh Co., Tokyo. Telephones, PBXs, faxes, modems, personal digital assistants, optical-character readers, printers, copiers, and computers will all communicate with one another. Like NT itself, Microsoft at Work is based on a layer of software acting as a buffer between the manufacturer's hardware and the rest of the system software. And manufacturer and user alike can add to software.

Unlike NT, however, the Microsoft at Work OS will support real-time, preemptive multitasking, and it will require much less RAM than the 16 megabytes that NT needs to run in a reasonable fashion. Microsoft at Work devices will communicate with Windows operating systems using Microsoft's message application binary interface (MAPI).

What puts real teeth in Microsoft at Work is industry support. Over 70 companies worldwide—among them AT&T, Bell Atlantic, British Telecom, Casio, Cannon, Compaq, Ericsson, Hewlett-Packard, Intel, MCI, Motorola, NEC, Oki, Philips, Ricoh, Sprint, Toshiba, Xerox, and Yamaha—are committed to supplying Microsoft at Work products or services.

The scope and breadth of Microsoft's attack has finally driven the Unix community

Richard Comerford Senior Editor

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to get its act together. On Oct. 11, 1993, the networking software giant Novell Inc., Provo, Utah, turned over the Unix trademark to X/Open Co., the Reading, UK–based international open-systems organization, whereupon Unix finally stopped being the pawn of competing companies.

The Open Software Foundation (OSF), in Cambridge, Mass., issued standards for a distributed computing environment (DCE) last year that allow Unix systems produced by competing vendors but in compliance with those standards to operate easily together in a network. Rivalry among tool vendors has already heated up—it's a "dog fight," according to Rich Hug, senior vice president of research and development at Softool Corp., Goleta, Calif. Softool, the leader in software change- and configuration-management tools, is delivering CCC/Harvest, a DCE-compliant client-server package for heterogeneous networks, this month.

OSF continues work on standards for the distributed management environment (DME), with whose help administrators could observe, maintain, and control heterogeneous networks. The standard should be released officially later this year, but 1993 saw companies begin positioning themselves to supply integrated, DME-compliant suites.

There were lots of rumors last year about what is coming next in operating systems. The scuttlebutt about future offerings from Microsoft, IBM, and Taligent suggests that those OSs will be built on a kernel like Carnegie Mellon University's MACH, because that is better attuned to working with software objects. In other words, they sound a lot like NeXTStep, from NeXT Inc., Redwood City, Calif.

NeXT's operating system may just be tenacious enough to survive until the world is ready for a new approach to computing; the $10 million injection NeXT received from Sun Microsystems should help keep the OS alive. With NeXT opening up the OS and rechristening it OpenStep, the product will certainly have undergone more thorough testing and debugging than its competitors by the time they are released.

WHY NEW HARDWARE? Whether or not companies decide to commit themselves to a major shift in their core software, they seem ready to splurge on new computer hardware. In light of the degree to which low-end systems have penetrated the market (a poll of *IEEE Spectrum* readers last year found that over 90 percent had PCs at work and at home), shouldn't sales of new systems meet with high resistance?

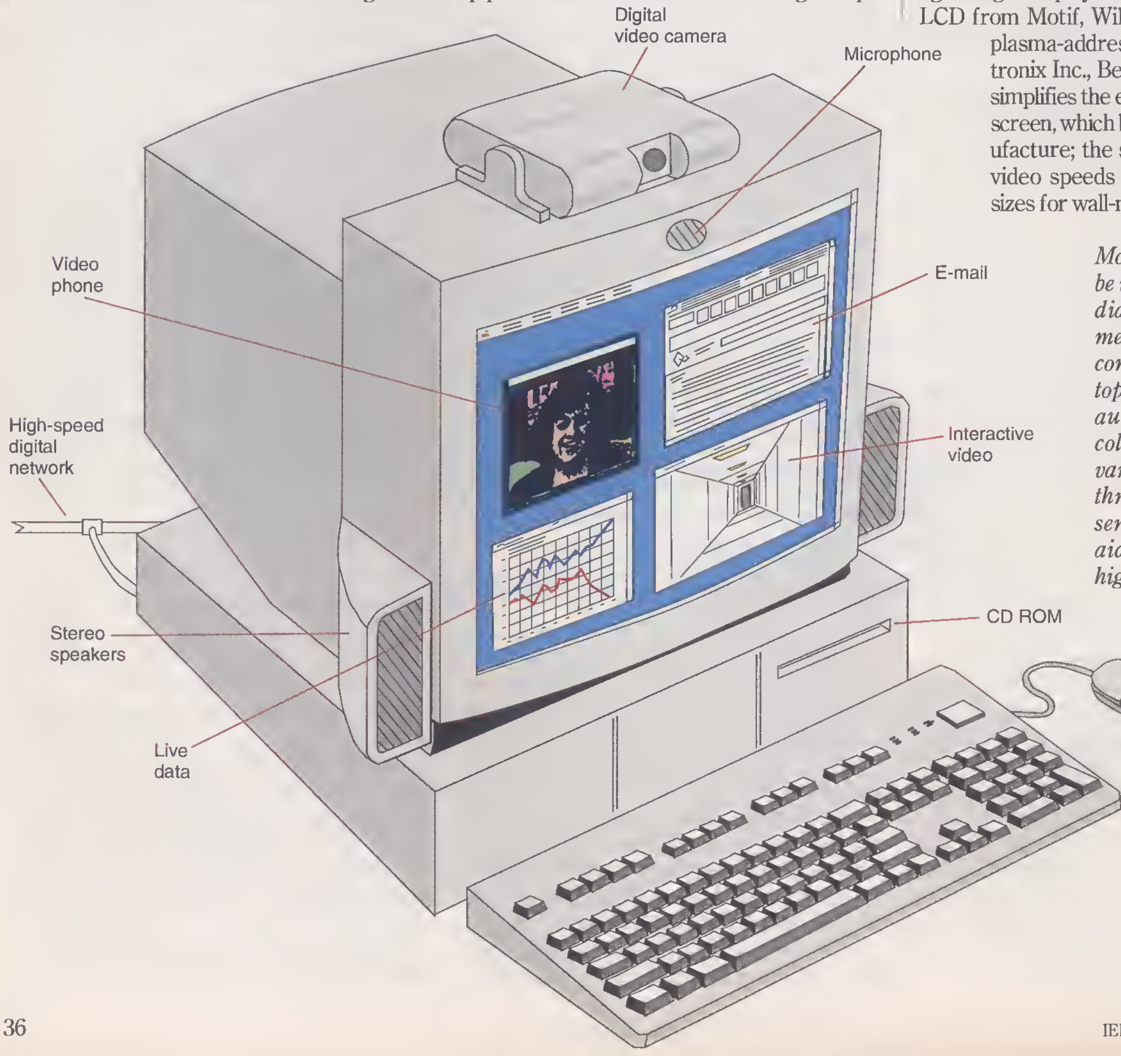
Perhaps not. Luckily for computer suppliers, there is a real need for more power. Resource-hungry applications like interactive multimedia and computer-integrated video teleconferencing have gone from being pipe dreams to necessities. Although corporations may not be happy about the need to accept shorter hardware life cycles, many are now amortizing small and mid-sized computers on a three-year basis.

Thus the search for better performance will translate into sales, and the battle for the high ground goes on. When delivering the four-processor version of the SparcStation 10 in early 1993, Sun Microsystems Corp., Mountain View, Calif., could claim it was the highest-performance system on the market. Last fall, Digital Equipment Corp., Maynard, Mass., had laid claim to the title for its current systems and demonstrated a 320-MHz alpha system as a statement of where its technology is going. Taking the most conservative view, RISC clock speeds will double during the next two years, so the top of the hill has not been reached by any means.

High-performance Alpha- and PowerPC-based processors will appear not only in desktop systems, but in notebooks and subnotebooks as well.

DISPLAY TRENDS. Portable and notebook computers remain the strongest force driving new screen technologies. Although the display industry has already invested heavily in manufacturing facilities for active-matrix liquid-crystal displays (LCDs), that did not stop several designers from conjuring up new technologies [*Spectrum*, November, p. 18].

Two of the more promising candidates for lightweight displays are an active-addressing LCD from Motif, Wilsonville, Ore., and the plasma-addressed display from Tektronix Inc., Beaverton, Ore. The first simplifies the electronics built into the screen, which becomes easier to manufacture; the second can perform at video speeds and be made in large sizes for wall-mounted flat-panel tele-



More workers this year will be using personal multimedia systems as their chief means of computing and communication. The desktop systems will provide audiovisual contact with colleagues, access to time-variant information, and three-dimensional representations of computer-aided design data over high-speed networks.

MOTHERSOLE: In the end, the best technology usually wins the battle

VIEWPOINT

Last year was another big year for the microprocessor. New devices appeared from leaders in semiconductors (Intel and Motorola) and workstations (Sun Microsystems, Hewlett-Packard, IBM, and Digital Equipment); clones also showed up from Advanced Micro Devices, Cyrix, and Texas Instruments. Fueled by all this activity, the debate over the architecture of future computers heated up still further.

On the one side, Intel and X86 clone makers such as Advanced Micro Devices (AMD) and Cyrix are fighting to maintain the domination of the X86 architecture. On the other, makers of reduced-instruction-set computing (RISC) chips predict that dire inroads into that domination will be made by their products' performance and cost advantage.

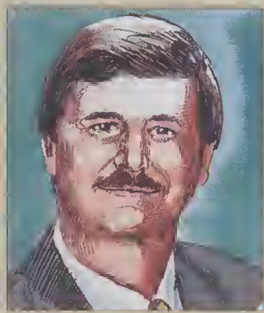
The real issue concerns the advancement and application of new technology—how industry migrates to and exploits new technology over time while struggling to maintain compatibility with the past.

Historically, businesses and consumers have moved to new technologies faster than predicted. A few examples are the color TV, the compact disc, the cellular phone, and the personal computer. Originally, all were said to be too expensive or too complex to become a dominant standard. Yet each went on to become a market success.

In the PC arena, the industry migrated from 8- to 16- to 32-bit microprocessors in little over a decade. Before each migration took place, it was argued, again, that compatibility and cost made it not worth the effort to move the installed base. Yet software applications moved quickly to exploit the latest in microprocessor technology.

As a late entry, IBM was expected never to amount to much in the workstation market. But thanks to an excellent combination of advanced superscalar processor and compiler technologies, Big Blue rose to be one of the top four workstation suppliers in its first few years in the business.

What drives this migration to new technology? There are several factors. First, new and enhanced applications always emerge to latch onto the latest advances. The newest advanced user interfaces from operating-system and application vendors always seem to require as much or more performance than is currently available. Ever notice that whenever you upgrade to the latest PC model, you seem to run out of processor performance or disk space shortly after the next releases of your applications are installed?



'If technology usually wins out over time, success comes down to which architectures and which companies can best exploit new technology quickly'

As object-based environments are adopted, the need for performance will accelerate again. In addition, software environments are moving steadily toward hardware and architecture independence. A greater number of portable applications and operating systems make technology consumption and migration easier. Finally, users want choice. The open systems dream of the '80s still lives.

So if technology usually wins out over time, success comes down to which architectures and which companies can best exploit new technology quickly. Take the RISC versus CISC debates. For the market to truly take advantage of RISC, it must *demonstrate* its superiority over CISC—no easy task, in view of Intel's skill at squeezing every last ounce of performance out of the X86 architecture. But if RISC gains a performance advantage, the market will move.

In terms of exploiting technology, there is another angle to consider. Compare the X86 and PowerPC product families. On the one side, there are Intel, Cyrix, and AMD, all competing head to head in the market. The result is three independently developed product lines, all with about the same set of products—multiple versions of 386, 486, and so on.

Now look at PowerPC, where Apple, IBM, Motorola, and others are working together to define and produce a common set of products. Joint processor development yields the latest products for low power, for low cost, for desktop, and for high-performance applications, all developed in parallel; the resources are coordinated, not competitive.

The great debate will continue throughout the '90s. This year may see the resolution of some issues as RISC-based personal computers are introduced and the next round of processors from both sides appear.

Great marketing can sometimes delay new technology, but it cannot stop it. Over the long haul, advanced technology usually wins out.

Dave Mothersole (M) is vice president and director of engineering for Motorola Inc.'s RISC Microprocessor Division, Austin, Texas. He is responsible for Motorola's work in developing PowerPC chips.

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vision. (The first commercial flat-panel TV was introduced in Japan by Matsushita Electric Industrial Co., Osaka, with a hefty price of ¥288 000 to match its hefty weight of 16 kg.)

Meanwhile, other Japanese companies are looking to improve LCD computer screens by going from a glass substrate to a plastic one. A recent study by Japan's K&T Institute shows that development programs to put plastic LCDs into mass production have revived. The study suggests that 640-by-480-pixel displays destined for portables (where their light weight and durability would give them a strong advantage) could be in mass production sometime between 1995 and 1997.

A recent technology development may turn notebook screens into true stereoscopic, virtual-reality-ready displays. VREX Inc., Hawthorne, N.Y., has developed a plastic laminate called μPol that overlays microscopic polarizers on a flat screen. Donning a lightweight pair of polarized glasses, the observer sees three-dimensional images.

The convergence of multimedia and desktop teleconferencing was first seen last year in the Indy system, from Silicon Graphics Inc., Mountain View, Calif. Leveraging the advanced three-dimensional graphics for which the company is known, Indy is the first low-cost system (under $5000 in a diskless version) to offer a built-in digital color video camera. Included in the bundle is Indigo Magic, a new environment for manipulating multimedia.

Last summer, Apple Computer Inc., Cupertino, Calif., sought to strengthen its position in desktop multimedia by introducing the AV series of multimedia-ready systems. It also began shipping the first computer display with built-in stereo speakers and microphone. Not to be left out, Toshiba Corp., Tokyo, introduced the first "portable" multimedia system, but its size and weight really make it a transportable system for bringing presentations to customer sites.

Helping to make multimedia a reality this year (Dataquest forecasts a triple-digit increase in multimedia-related sales in 1994) is the peripheral component interface (PCI) local bus. Hammered out by hundreds of original-equipment manufacturers, tool makers, and vendors, the low-power bus can move data at 132 MB/s, easily fast enough to keep up with high-frame-rate video. What is more, the architecture is not tied to any specific microprocessor, so hardware can be switched between systems.

IN STORE. Spurred by the market's hunger for multimedia [*Spectrum*, "Interactive Multimedia," March 1993, p. 22–39], the real growth in storage systems this year, like last year, will take place in compact-disc (CD) ROM drives. Demand not only for multimedia-ready computers and add-on players but also for CD-ROM recorders will rise sharply.

Today, CD-ROM recording hardware can be added to a computer for under US $5000, and a recordable disc costs $18 or less. So the hardware is affordable by anyone who wants to "author" a disk, even for such limited publication runs as marketing presentations or newsletters. The publishing industry has already jumped on the bandwagon, and CD-ROM publications like *From Alice to Ocean* are setting high standards. ◆

Software engineering

As this business plows ahead into 1994, its course is being altered by two factors: object-oriented programming techniques, and client-server technologies. Neither is exactly new, but they have finally reached the stage of development where they are prepared to enter full-scale deployment. While both are sometimes confused with markets, they are in fact valid programming techniques. Now they are being widely accepted after some years of discussion between tool and software-application developers.

Both technologies promise better deployment and utilization of current and future resources. Client-server techniques distribute processing tasks across the network, letting the systems or software best suited to a particular task handle it. Client-server is somewhat similar to distributed processing, which was all the rage several years ago, except that task distribution is based more on functional fit than on processor availability.

Object-oriented technology lets an object—a software entity consisting of the data for an action and the associated action—be reused in different parts of the application, much as an engineered hardware product can use a standard type of resistor or microprocessor.

Underlying the acceptance of object-oriented methods of software development is a real concern for programming productivity. But object-oriented languages and methods make nonsense of the former standard approach to measurement—counting lines of code–and function points seem to have taken over. According to Capers Jones, president of Software Productivity Research Inc., Burlington, Mass., the Function Point User Group holds conventions attended by more than 300 companies plus all of the Fortune 500.

CASE BACKLASH. The original answer to programming productivity problems—computer-aided software engineering (CASE)—has not been the panacea promised by earlier hype, making many in the industry reluctant to use the acronym. But surely the term is a natural way to describe techniques of developing (or engineering) software with automated help from computers. As Jones said, "CASE suffered in the past from being primitive, but it is improving. This year vendors are adding project-management support and quality support."

He adds that a significant problem in the software-engineering arena is the basic need to make software development easier. So today, he said, object-oriented methods and CASE are both being used as tools for building client-server systems.

Although they are receiving much attention, Jones believes client-server applications are numerically a small part of the development projects going on. He estimates that one half of software programming is information systems applications, one quarter is military, and one quarter is system software for real-time control applications. Client-server development makes up about 10 percent of the information-systems development, he estimates.

Still, even CASE tool vendors report some image problems. "The customer associates CASE with claims of productivity gains," said Rob Pritt, president of Evergreen CASE Tools, Redmond, Wash. "CASE wasn't the solution, but good methods, management, and so forth were. The results of CASE have been products that weren't late or over budget, which is better than late or over budget. But everyone expected early and under budget [programs] or better, more accurate [development]. Now end users are wary—the need is to sell on benefits, not hype." Evergreen, whose products started as shareware, makes development tools that run on PCs and under Microsoft Windows.

What software developers do to streamline their work, cut costs, and rid the final product of error remains CASE, whatever else it may be called. But to overcome that term's negative connotations, new names are developing to replace it. For example, Mercury Interactive refers to "automated software quality," a term that more closely describes what the company's tools do, according to Amnon Landon, chief operating officer.

Tools from the Santa Clara, Calif., company let software developers test their work as they go along. Having this capability not only improves software quality by catching bugs, it also saves money. Bugs cost more to remove the closer it is to the time to product release, and the fewer bugs there are in a final release of a software system, the less maintenance is later incurred.

Mercury's XRunner is an automated software testing system that runs under Unix X Windows. It uses object-oriented text to record and replay test operations, and its built-in Test Script Language (TSL) enables developers to write a test program while working on an application program. Testing can run overnight or over a weekend. The company's WinRunner software is similar, except for running under Microsoft Windows.

Software engineering has many think tanks and user organizations at work on improving the discipline. Jones's organization is one. Another is the Object Management Group (OMG), Framingham, Mass., whose goal is standards for the use of object-oriented techniques in developing software. With the growing use of object-oriented programming languages such as C++ and with the increased complexity of software, the standards are catching on.

Chris Stone, OMG president, told *IEEE Spectrum* that object-oriented technology works well not only in its own right, but with client-server computing as well. "A very hot topic is to distribute object technology using an abstract interface," he said. Programmers can use an object to deliver data to a client or the workstation, rather than specify a transportation protcol like TCP/IP. "It makes life a lot easier for distributed development applications," Stone said.

For now, OMG has been focusing on object-oriented technologies for the GUI and the operating system, but Stone sees a big opportunity for object-oriented transport tools. "Transport-oriented software tools are pretty bad, and that's changing. That's what will drive client-server technologies," Stone predicted.

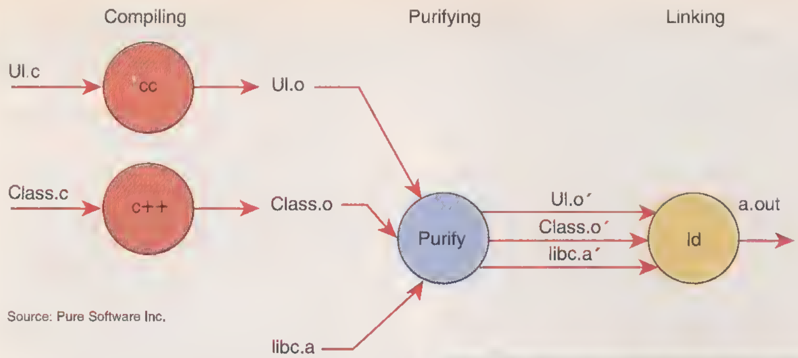
He added that widespread adoption of distributed technology and abstract interfaces will lead to a polymorphic interface. Such an interface would allow for the use of one interface for many different functions and environments, and would allow industry to finally realize the promise of object-oriented software."Then you could start to develop a component software business," he said.

Having such components would not only provide a new opportunity for marketing software. Being able to design software systems using components—ones that could be pretested and fully debugged before they are

HIGHLIGHTS

- **Object-oriented technology gets moving**
- **Client-server makes headway**
- **Craft must become industrial process**
- **Quality is a universal concern**

David A. Gabel Contributing Editor



Pure Software's Purify reads object files generated by existing compilers, adds error-checking instructions, and feeds the output to existing linkers. Existing debuggers continue to work with purified code.

delivered to the user—would place software engineering on a more solid footing. Stone believes this will also be a major benefit; he said, "We need less art and more engineering. [Software development] should be a real engineering discipline."

Like Jones, Stone is a proponent of making the tools easier to use. He notes that most people derive tools from a language base, as has been the situation with CASE. But people using CASE tools need some framework, which is why companies have been adding GUIs, object builders, object request brokers, and the like. "The GUI crowd's moving in that direction," he said. "Microsoft, for example, will make OLE [object linking and embedding] more distributed for Microsoft products."

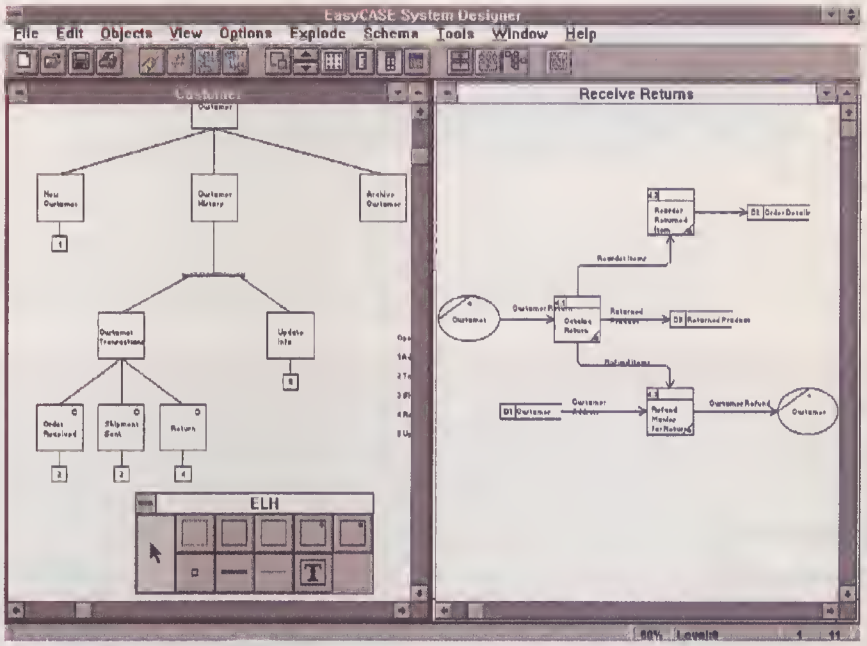
ALL ABOARD. For tool makers, it's an object-oriented bandwagon by now, according to Lou Mazzucchelli, vice president and chief technical officer of Cadre Technologies Inc., a leading provider of CASE tools. Located in Providence, R.I., his own company produces a tool called Object Team, which supports the Shlaer-Mellor methodology for object-oriented programming, used mainly by people involved in mission-critical applications.

Jones sees the mission-critical, system-software side as a hot ticket for object-oriented programming. But the military, which he points out is a very large user of such software, is generally lagging in the object-oriented and client-server area; it is still using Ada versions for development, rather than the newer object-oriented languages.

But the evolving nature of object-oriented technology creates problems for the tool makers. Referring to the numerous methodologies now being used or in development, Mazzuchelli said that "there are a thousand points of light," and each has its adherents. Software-tool developers find themselves in the position of having to satisfy the demand for all of them, or at least those that are generally in use.

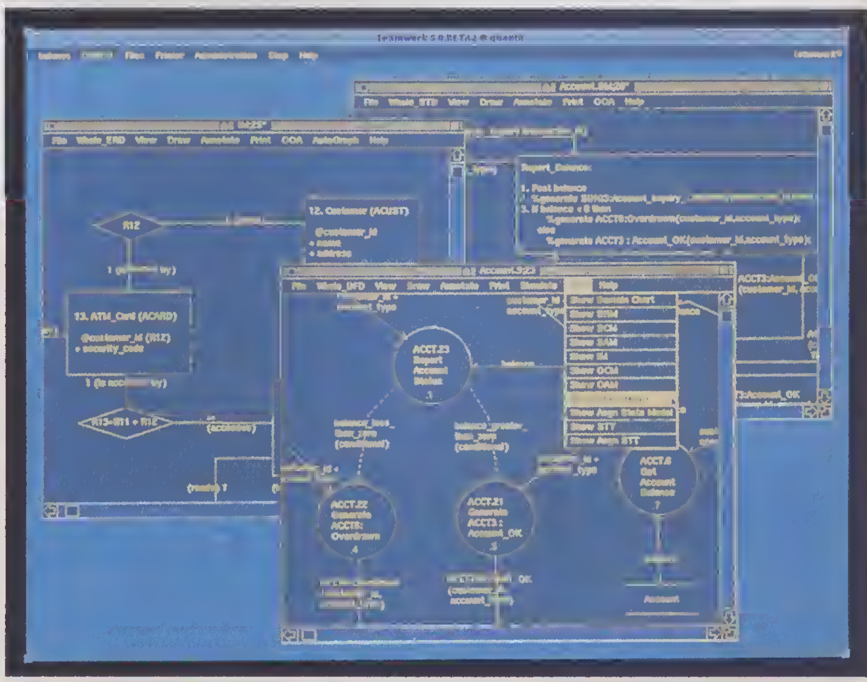
For instance, the method developed by Rumbaugh et al. is widely used, as is Shlaer-Mellor. "We are not telling people what church to go to," Mazzucchelli said, "but we are trying to sell the religious artifacts." The company recently announced a new product that encompasses these two techniques, called Ensemble Viewer, and is also planning a major revision of its product Teamwork, to be introduced early this year.

Evergreen, too, will bring out a CASE tool that will support several object-oriented methods. Called EasyCASE for Windows, it will incorporate Shlaer-Mellor and Rumbaugh et al., although Pritt said Shlaer-Mel-



Evergreen CASE Tools

Evergreen Software's EasyCASE 4.0 can present a number of views of a software application under development. On the right is a data-flow diagram, while the left side of the screen shows an entry life history.



Cadre Technologies Inc.

Software engineering tools, like tools used for hardware engineering, present software in graphical terms for the engineer. Teamwork OOA, from Cadre Technologies, produces a representation that focuses on objects and their relationships and behavior.

lor is becoming outdated. "There are quite a few technologies available," he added, "and they are gradually being adopted by us and other CASE vendors and by the users."

"So far, we have seen the early adopters," said Pritt. "By about the middle of next year, people will really be using it. The object-oriented authors are maturing, the third editions of their books are out, and they are bringing out their own tools."

Object-oriented techniques are well suited to real-time systems, which are used heavily in engineering applications. Although good engineering requires a common way of expressing designs and common design standards, those elements are misssing for software architectures.

"What is a software architecture?," rhetorically asked Dave Nettles, director of process improvement at the Software Productivity Consortium, Herndon, Va. "How is it represented, and what does it represent in software? There is no general agreement." Nettles said that with hardware changing as frequently as it does, and software changing to keep up, clear definitions of architecture are vital. "We're working on it," he said. "We have a software-reuse program that attempts up to seven views of the architecture."

GOOD FOR BUSINESS. Defining different ways to look at architectures, with the aid of object-oriented techniques, will probably help consortium members who work on real-time systems, such as aircraft-control software. It should also help business developers in the transaction market, who are busily developing client-server applications. In fact, client-server techniques, largely used in commercial software development, can complement object-oriented techniques, according to Mazzucchelli. "Some people get confused, thinking they are exclusive," he said. "But they are orthogonal, they do not compete. You could build batch applications with object-oriented technology."

"With the workstation," said Mazzucchelli, "you can tightly couple the graphics with the processor," which eliminates the need for a network host to perfom GUI generation tasks. "So 99 percent of all client-server work today is offloading the GUI to the desktop. As the networks got better, then distributed computing became possible, and that made client-server computing possible. Now we have to come up with the tools to handle the applications."

Client-server technology started to appear in 1993, agreed Evergreen's Pritt. "It's already getting like expert systems a couple years ago, when it almost seemed people were saying, 'Buy this car, because it's got expert-system technology.' " Evergreen is working on a client-server tool now, and has just signed a joint-development agreement with PowerSoft, a maker of client-server development tools in Burlington, Mass.

Of equal importance with client-server and object-oriented methods is the push for quality improvement and process improvement. Vendors, users, and large software developers all are concerned. "There is a growing frustration with producing quality software," said Mark Box, vice president of Pure Software Inc., Sunnyvale, Calif. "Battles in the database industry for the business of ISVs [independent software vendors] are being fought on quality, not features. Service, support, and reliability are becoming more

TROY: It's time to make software development an industrial process

VIEWPOINT

Software development will have to become an industrial process before computer-aided software engineering (CASE) can fulfill its potential. In the '80s CASE had the reputation of being a luxury. But if management makes a commitment to this area's industrialization by such means as capital investments and parts reusability, CASE can become a competitive necessity that will take the field into the next century.

First, though, we must develop a critical attitude to application development as it is today, questioning its deepest assumptions and analyzing the changes that must be made, by programmers as well as management, if software is to achieve mass production. For if software engineering does not change, it will lose its ability to respond competitively to customer-driven opportunities.

The CASE of the '90s therefore must be buttressed by industrial doctrines such as capitalization, continuity of production, reusability of components, and asset management—the tenets of a new world economy. The coincidental emergence of object-oriented environments is already supplying libraries of reusable software objects. And as the decade unfolds, management will have to remodel software engineering so as to be able to measure programmers' performance against corporate fiscal practices and policies.

The programming community is resistant to such a change, by and large. It prefers the view that it is a village of artisans. Tempers can run high, output can slow to a trickle, and persons with lofty degrees are quite content to sit at their workstations and write code character by character. A mythology of hand craftsmanship and wizardry permeates the activity of too many practitioners.

In contrast, an architect designing a building analyzes the environment in which it is to be situated, defines the design parameters, calculates the stress levels and dimensions, and then draws up a blueprint; the architect does not painstakingly lay bricks. Today's software engineers are the equivalent of bricklayers, not architects.

'We have found that object orientation's reuse capabilities increase productivity overall by at least 50 percent, with no limit in sight'

Some pundits assert that the way to better software development lies in re-engineering, the latest buzzword. But a close scrutiny of the present state of affairs is likely to reveal that software engineering has no methodology at all, and therefore nothing to re-engineer. Managers have settled into a routine that, despite a torrent of new tools such as object orientation and second-generation CASE, recalls the days of punched-card programming.

Whatever the reasons for this area's lack of a true engineering process—whether resistance by programmers, technological flux, or managers' resignation to long turnaround times—they can no longer be tolerated. We are about to witness the engineering of software development (and then, perhaps, its re-engineering). The transition is comparable to the industrial revolution, when craftsmanship was overtaken by economies of scale that applied reuse and mass production techniques on a grand scale .

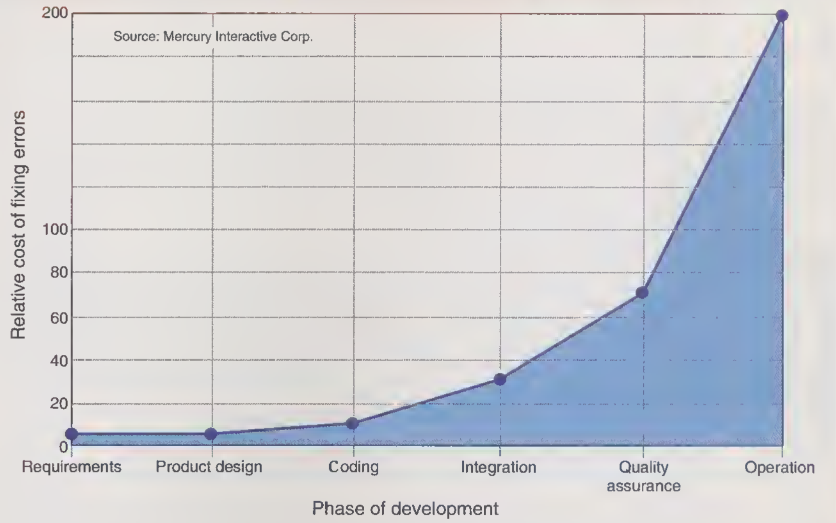
The first wave of the software engineering revolution attempts to utilize the practitioner's holistic knowledge of the development process. High-level modeling techniques, embedded in object-oriented tools, and second-generation CASE can automate code generation. As a result, programmers will "engineer" programs, rather than grind out code. Visualization, for instance, will improve the quantity, quality, and creativity of their output by orders of magnitude.

To avoid past mistakes, though, we can no longer afford a blind faith in technology. Object orientation, the latest craze, must do more than dazzle the marketplace with its kaleidoscopic array of features. Software engineering must adopt the sober methods of civil, electrical, and other engineering disciplines. After all, the new world economic order is predicated on rigorous time-to-market schedules.

At the core of this new paradigm will be reuse. Just as other engineering disciplines are structured around a core assumption, software engineering will combine technology with industrialized processes to achieve maximum reusability of software. In effect, reusability is at the root of an industrial software-engineering process, in which the parts bin becomes a library of software components.

We have found that object orientation's reuse capabilities increase productivity overall by at least 50 percent, with no limit in sight. The capitalization of reuse libraries—that is, considering them corporate assets—

Rising cost of fixing errors as development advances



As the software development project moves towards completion, the cost to repair an error in the application soars. Development economics thus argue strongly for testing and tuning software as early as possible in its life cycle, preferably before the integration phase.

important. [Increases in] productivity are coming mainly because of improved quality, since big applications are harder to get right."

Pure Software delivers testing and analysis tools to the developers that let them tune the code as they are developing it, by analyzing run-time performance, for example, or by looking for memory leaks, important in graphic applications. The company designed its Purify package to find run-time errors and last year improved it with incremental linking. This technique, by relinking only those portions of code that have been modified since the last link, saves up to 90 percent of the link time needed for application development. Its Quantify package, on the other hand, checks for run-time performance, so that the performance can be tuned.

Higher-quality software needs less maintenance, and so costs the developer and the user less. This is the same phenomenon in software as in hardware. Hardware companies of all kinds that have made commitments to quality standards, such as the international ISO 9000 guidelines, find that the cost of attaining the required quality levels is offset by savings accruing from the increased product quality they enjoy. "Seventy to 80 percent of the cost of software development is maintenance," said Stone from the Object Management Group. "And maintenance hasn't changed much." He added that usually a user's system crashes because of an unforeseen software problem, and developing code free of such errors becomes harder the more complex systems get. All these efforts—object orientation, reusable software, client-server structures—are aimed at finally turning the art of software development into an industrial process; to engineer it, in short. Nettles said that just as hardware improves every five years, so should software.

NEEDED NOW. In fact, it's no secret that software is badly in need of that hardware capability today. Nettles pointed to the Motorola-Lockheed Iridium project—a global network of communications satellites for personal communications—as an example of a software project that needs good industrial methods. "The amount of software in that boggles the mind. We need industrial practices to define the software and we need to get repeatable software to improve the process. That has been missing in the past, but now there is a big movement to get to that."

The capability-maturity model is a big driver in the DOD [Department of Defense], he noted. This model has been developed by the Software Engineering Institute, and has been adopted in the DOD to the point that requests for proposals will state that a bidding company must commit to improvement or have attained a certain level."It is much like ISO 9000," he said. "You cannot sell in Europe unless you have ISO 9000 certification."

Of course, measurement of software development processes is critical to their improvement. Nettles pointed out that no one can institute statistical process control on a process that varies widely as it goes along. "That's why the thrust is process," he explained. "There is a definite relationship between changes in process and improved quality or reduced time. People used to do testing with a big super integration test, but have found that it is more productive to do testing along the way. [Today] the new testing is not just executing the software, but trying to be sure that the requirements are right in the first place," he concluded.

Stone also thinks that using object-oriented techniques will require a change in the way productivity is measured. He noted that, with the object-oriented approach, software development could break down into creating classes—like a print object, for example—and a librarian to check the classes in and out. So productivity assessments will have to measure such activities.

Stone believes that object-oriented techniques, by allowing users to develop their own applications, will change the present application developer into a class developer, producing the classes of objects not only for development of a specific application but also for reuse. "If you make components cheaper and of higher quality," he said, "then you'll dodge a lot of maintenance headaches."

As the call for better quality and reduced maintenance gets stronger, as tools such as object-oriented methods make it possible to reuse code encapsulated into interchangeable objects, and as testing paradigms improve, perhaps the arcane craft of software engineering will indeed enter the industrial age. If it does, it cannot help but benefit all connected with the development of more and better software.

And as the role of the developer changes, so will that of the user, who, Stone believes, will be able to develop more of her own applications. Object technology, embodied in languages such as Microsoft's Visual Basic and Visual C++, is already doing that. ◆

provides management with a rationale for applying industrial process concepts to software development. Managers will soon see that staying the course in existing development programs may hurt their careers.

Reuse and industrial processes for software engineering come not a moment too soon. We have a user revolt on our hands. In the past, software was doled out by either a vendor or the staff of an internal management information system; both turned a deaf ear to the end user's concerns. The final product provided too little, too late. But the software marketplace has now been commandeered by users, as evidenced by the explosion of personal productivity applications and graphical user-interfaces at very reasonable prices.

Let us remember the lesson learned by those large corporate users attempting to migrate millions of lines of expensive proprietary code to distributed open systems. Those who wrote and documented all this proprietary software are long gone to other jobs. Now management has to deal with the consequences.

To do so effectively, managers must adopt three guiding principles. They must redefine the role software developers play within the corporate culture. They must see that reusability is incorporated into every program design. And they must insist that software production meet the same performance standards they would expect of any other industrial process.

Robert Troy is founder and president of Verilog SA, Toulouse, France. He is also chief executive officer of Logiscope Technologies Inc., Dallas, Texas, a wholly owned subsidiary.

Application software

Companies that deal in application software for electrical engineers found their territory expanding during the past year. The availability of highly capable hardware, as well as the introduction of the operating system, Windows NT, opened up the market to many new platforms.

In addition, users are demanding software that can cope with new tasks. Vendors of circuit-synthesis tools are finding that analysis must be coupled with design. Vendors of mathematical analysis tools, whose mainstay, has been numerical analysis, are now providing symbolic manipulation as well. Everywhere, vendors say, one of the principal pressures is the need to network engineers into corporate data, so that engineering design data may be shared with manufacturing, reliability calculations can flow from design work, and so forth.

To quote Doug Dennis, mechanical computer-aided design (CAD) segment marketing manager at Silicon Graphics Inc., Sunnyvale, Calif.: "I think from the end user's standpoint, there is tremendous pressure both to share electrical and mechanical data and to share it in a much easier fashion." The shorter time to market and packaging constraints everyone faces mean companies must be able to generate data as quickly as possible, and communicate it to everyone, he amplified.

THE GUI BANOWAGON. Everywhere, too, software companies are jumping on the graphical user-interface (GUI) bandwagon. Last year it became obvious that engineers must have the ability to visualize their data: it is hard and often impossible to spot trends in columns of printout, and much easier to find errors or anomalies in information given a graphical format.

For example, Scitech International, Chicago, a distributor and publisher of scientific and engineering software, offers a graphical data analysis package called Stat Lab, from the French company SLP SA. Stat Lab "is a statistical analysis tool with a high focus on exploratory data analysis," explained Ken Kornbluh, the company's president. It "is designed to be highly interactive. You don't need to go over the data set, because you can interactively work [in a graphical format] with the data that's been gathered."

David A. Gabel Contributing Editor

HIGHLIGHTS

- ***Windows NT draws all eyes***
- ***'Old software' is updated to do more tasks***
- ***DSP and RF tools mate for wireless systems***
- ***Suppliers take on many platforms***

Today, "the trend is more to Windows," he told *IEEE Spectrum*. "Anyone who is not there is trying to get there. Everyone is saying they're committed to Windows NT, and most are writing to the Win32 interface. That's what's happening from a technical point of view."

Indeed, a quick look at the catalog of applications for the Win32 interface for Windows NT reveals a 5-cm-high stack of applications, tools, development systems, and more—all aimed at that particular interface. C++ compilers are either available or coming soon from the publisher of Windows, Microsoft Corp., Redmond, Wash.; from Borland International, Scotts Valley, Calif.; from DECwest Engineering, Bellevue, Wash. (a Digital Equipment subsidiary); from Imagesoft Inc., Port Washington, N.Y.; and more. Fortran, too, is available, or soon will be, from Microsoft and from Absoft Corp., Rochester Hills, Mich. In addition, a variety of tools for instrumentation control, data analysis, math modeling, and design are all being ported to this interface.

CROSS-PLATFORM CAPABILITY. Such a groundswell has been generated because of the new operating system's cross-platform capability. Although a great many engineering tools run under the Unix operating system, most plain old productivity tools—spreadsheets, database managers, word processors, and the like—run on personal computers under DOS and Windows. The frequent result has been a less-than-optimum use of hardware.

"Many engineers today work in an environment where they have a workstation in their area for specialized applications," said Brian Moran, one of Microsoft's managers of technical evangelization (yes, that's the title he goes by). "But they also have a PC for some word processing or some electronic mail. Now, with NT, you don't need two" computers, he added.

Windows NT will run on MIPS R4000 processors, on Sun UltraSparc workstations, on Intel-based PCs and clones, and on the Alpha processor from Digital Equipment. No announcement has been made concerning Hewlett-Packard Co.'s PA/RISC (reduced-instruction-set computing) processor, nor has there been any official word on those Intel processors that are slated to follow Pentium, although it's a good bet that Windows NT will run on them as well. Also, Microsoft and Motorola Inc.'s RISC Microprocessor Division, Austin, Texas, will put NT on PowerPC turf, where IBM hopes to build its OS future.

Moreover, Windows NT is a 32-bit operating system that, unlike Windows 3.X, does not require DOS. Yet NT also runs 16-bit applications, the norm for productivity software packages, though as Moran admitted, "when an application touches the hardware [and bypasses the operating system], the emulation mode will trap it."

With all this hardware compatibility, it's no wonder that Digital Equipment is bullish on NT. Don Jenkins, worldwide director of electronics for the company's discrete manufacturing and defense unit, Marlboro, Mass., boasted that not only NT but also Unix will run across the whole line of Alpha systems, ranging in price from about US $5000 to about $900 000 (for enterprise file servers).

"Our initial announcement was for NT only, but at that time we stated that our strategy is NT and Unix across the product line," Jenkins said. "Many customers want to look at a platform that runs both, and with Alpha, you get the same system to do both."

The desire to move across platforms and operating systems is evident in all sorts of applications: packages for statistical analysis, design, verification, and instrumentation control, for example. What's happening is that the greater test and measurement world is wholeheartedly embracing open standards on which the computer business has been working, according to Chris Van Woerkom, product manager of Hewlett-Packard Co.'s VXI Systems Division, Loveland, Colo.

"Everyone's been on PCs and workstations, and suppliers aren't on just one platform, " he explained. "There are DOS, Windows, and Windows NT, and Unix variants as well. There is a lot more cross-platform work." Van Woerkom's product, HP VEE (for Visual Engineering Environment), has itself been ported to the DOS and Windows environments, and also runs on Hewlett-Packard and Sun workstations.

Van Woerkom added that at the front end of their software applications, people are offering more standardized interfaces. HP's standard instrument software (SICL), for one, is opening up its interfaces, and people are porting their software to it, a trend that

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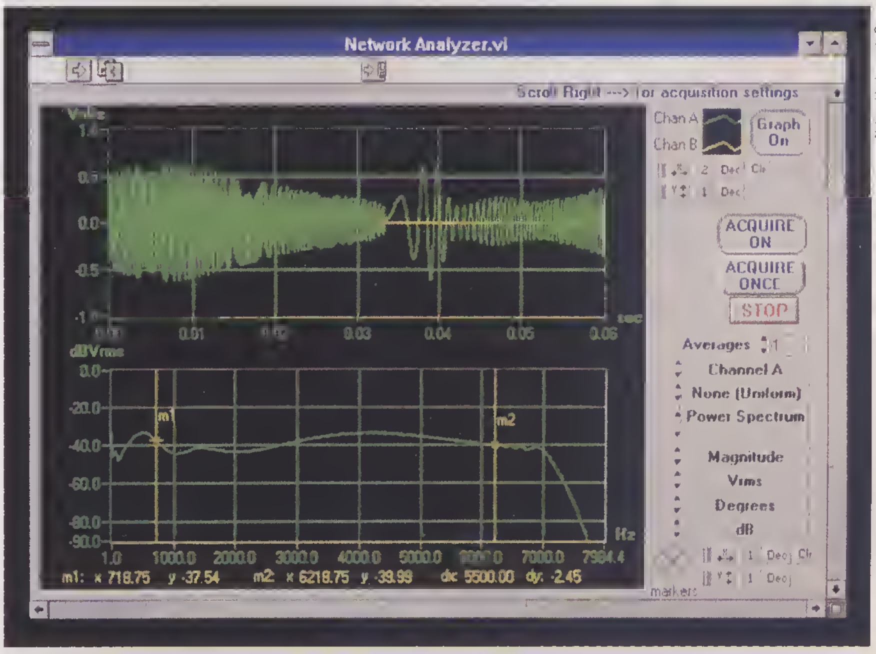
DSP Development Corp.

DADiSP software from DSP Development Corp. is used for analyzing real-world variables. Here data from an automobile engine test run are analyzed in a four-window worksheet using peak analysis, statistics, integration, and level counting and spectral-analysis techniques.



National Instruments Corp.

SpectrumWare from National Instruments Corp. is the kind of software application that runs on a variety of platforms—Windows, Macintosh, and Sun workstations. It allows the user to simulate a spectrum analyzer on one of the computers, and comes bundled with the company's signal-acquisition boards.

is quite recent. For example, he said, there is a version of VEE bundled with Data Translation's data acquisition products.

LabView, a competitor of HP VEE, comes from National Instruments Corp., Austin Texas. This package, too, runs on a variety of platforms, including Windows and Sparc workstations under Solaris 1.X or 2.X. Like HP VEE, LabView permits users to employ graphical methods to program the operation of instruments connected by the IEEE-488 instrument bus, the VXI bus, and RS-232 connections. Simply by indicating what instruments are connected to the system and how, users instruct LabWindows to generate a C program that supplies them with control and data-handling instructions.

At last year's Wescon show and exposition in San Francisco, National introduced a new package: LabWindows/CVI (C for virtual instruments), a 32-bit development environment running under Windows or X Windows on Unix-based SparcStations. National does not yet have a version for Windows NT, although software marketing manager Ray Almgren promises that one is under development. "Since LabView has a compiler in it, we have to do a bit of different porting. We have to cross-compile," he said.

GETTING THE JOB DONE. Notwithstanding all the ferment in operating systems, users still want tools that get the job done quickly and easily. That, declared Jim Tung, vice president of business development, is the mission of The MathWorks Inc., Natick, Mass.

"Our business is taking math and hiding it from the user," he said. "We create tools for doing engineering and scientific work without fooling with the math. We focus on the applications that can be derived from the math."

The company's product, MatLab, accomplishes this by providing so-called toolboxes that serve specific applications, such as control system design or signal processing. MatLab for Windows has just been introduced.

Something else is happening at the company, too: it has continued to integrate different functions into its products. "MatLab always had numerical analysis," explained Tung. "We just announced a new toolbox for symbolic computations." A partnership with Waterloo Maple, the developers of the Maple language, made the computational kernel of Maple available for a toolbox.

According to Tung, this combination of tools for numerical and symbolic manipulation will be useful to people working with systems modeling. In the past, he said, there were no packages that provided for symbolic manipulation as well as numerical analysis, so users who needed both had to have two programs. But "that was all import/export driven," he noted, which is not "how engineers want to pursue workflow. The trend is for the environment to include all those functionalities [engineers need], so that users can work in a much more continuous fashion."

As for the proliferation of microprocessors—and platforms—that will run engineering-tool software, Tung sees it as something that will be confusing to customers, at least in the short run. But he said it would have little impact on MatLab tools. "We, like many, are in the mode of wait and see how they [new systems] perform, and how people will use them," he said. But he foresees people continuing to work in a heterogeneous environment, with a mix of machines, with no one manufacturer winning out. "So it's important to have the tools work well in all possible environments," he concluded.

DADiSP, which uses the worksheet metaphor to display and analyze data, resembles MatLab. DADiSP creator DSP Development Corp., Natick, Mass., also introduced new instrumentation control modules last year, as well as a 32-bit Windows version of its software and a module for statistical analysis. In fact, the list of hardware that DADiSP supports reads like a who's who of

computer workstations, including as it does PCs, Sun SparcStations, IBM RS/6000 workstations, HP 9000 workstations, Digital Equipment VAXs, Alpha AXP workstations, and Silicon Graphics workstations.

Product manager Lisa Kempler of DSP Development said that her company's customers inhabit surprisingly heterogeneous environments. They have Sun servers, HP workstations, and DOS/Windows machines within the same lab. There has been a lot of movement to Windows, but "we kept things very portable using C and X," she maintained. "It is fast and OS independent. For our new version 3, it took only a month to port to all platforms that we support."

She pointed out that DSP Development sells more applications for PCs and clones than for any other group. But there is as much interest in it for workstations as for PCs, despite new Windows systems and new processors.

"Windows NT, from our perspective," she explained, "is nothing but another platform to port to." There is also the Unix standard to port to. "It's more work for the producer, and the user has to choose," Kempler continued. DADiSP is not yet available for the Windows environment.

The DADiSP program is a visual-analysis and data-acquisition tool. People have learned that studying tables is unhelpful. Engineers analyzing data know what they should be seeing, and can look for the patterns they want, to see if they exist. The problem is that in many applications, such as a process control environment, so much data is available that the picture can become quite clouded. DADiSP, claimed Kempler, makes it easier for users to get the information they need and to display it in an easy-to-analyze format.

A COMING EXPLOSION. Engineers designing high-frequency systems found out last year that one of their sources for design and analysis software, EEsof Inc., Westlake Village, Calif., had been acquired by another of those sources, Hewlett-Packard.

HP EEsof was founded in 1983 to develop and sell microwave design software. At first, 80 percent of its sales were accounted for by microwave tools and the remainder by RF tools, but over the past few years those proportions have reversed exactly. The coming explosion in the market for such digital communications products as cellular phones, global positioning systems (GPSs), and wire-

CHILDS: New all-in-one tools will increase designers' productivity

VIEWPOINT

As a young engineer in the early '70s, I helped design a satellite system primarily intended for applications in digital communications. I can vividly remember marketing analyses that showed how relatively little commercial communications data was transmitted in digital form at that time. This particular satellite system, despite the designers' best intentions, wound up providing mostly good old analog television services in the 12- and 14-GHz bands. Digital communications services simply did not develop as quickly as had been anticipated.

Today, of course, the use of data communications is huge and ever increasing. Examples include communications based on fiber optics, very small-aperture terminals, and wireless local-area networks, as well as digital cordless and cellular telephones.

As for the future, virtually all communications systems will be entirely digital, with the analog variety becoming an anachronism. It's very clear that, as predicted by such visionaries as William Gates (*Information at Your Fingertips*) and George Gilder (*The Telecosm*), the second half of the Information Age will see the commonplace use of computers and the data they process sent over digital data communications networks causing startling social change.

'It's very clear that... the second half of the Information Age will see the commonplace use of computers and the data they process...causing startling social change'

A consequence of the growth in new communications systems is a rising level of design activity. Indeed, the number of new design starts may be growing exponentially. What is more, the increase in this activity comes with an increase in design complexity. The designer responsible for developing new communications systems and components must deal with a complicated, challenging environment. Digital data must be processed, modulated onto an RF waveform, and transmitted through a noisy and nonlinear channel full of interfering signals and other impairments. Then it is demodulated and processed once more, to yield the original data. One of the most exciting recent developments in this area is the growing use of fairly complex digital signal-processing (DSP) circuits or systems to compensate for noise, nonlinearities, interference, and fading.

But this messy environment, with all its less than ideal characteristics, demands new kinds of design tools that will allow the engineer to address all a design's problems at once. He or she can select these tools from two broad categories: those that emphasize the simulation and design of the DSP portion, while characterizing the channel rather simply and idealistically, and those that emphasize the physical modeling of the channel and treat the DSP portion as part of the overall validation. The former type is generally favored early in the design process, during the "thinking" or conceptual stage. The latter is probably used more in the "doing" or implementation stage, where the chief concern is that the system or subsystem meet its specifications—regardless of the non-ideal behavior of its constituent components.

Some designers are turning to convolution coding and Viterbi decoding for the signal processing in digital communications systems. Digital data can be coded at various rates on the transmit side and decoded on the receive side, leading to impressive gains in error-free transmission for a given transmit power. The available Communication System Modeling results for these codes in the literature are based on ideal filtering and white Gaussian noise.

These are fine so far as they go, but the working communications engineer has to deal with many more impairments than these simple tools can handle. This is where modern system simulators are invaluable; they can simulate the ideal effects and also allow the designer to examine the effects of real-world impairments, such as non-ideal filtering, amplifier nonlinearities, interference, fading, and a host of other factors.

One of the most exciting developments in communications is the likely widespread adoption of spread-spectrum systems for use in the crowded, band-limited portions of the spectrum typically found in urban environments. These code-division multiple-access (CDMA) systems have been shown to offer the highest capacity in such environments. One of the more challenging parts of this design is ensuring that the pseudo-noise sequence at the receiver is synchronized with the transmitted pseudo-noise sequence. Using a modern system simulator, a designer can analyze the efficacy of various hardware implementations.

As the use of digital communications becomes more pervasive in our work, system architects and designers will be creating and validating other systems, which will be as complex as those built around spread-spectrum technology. With the new kinds of electronic design automation tools now emerging from suppliers' workshops, that design will be accomplished seamlessly, and in less time. These tools will make designers more productive, reduce time to market, and help to usher in that second half of the Information Age.

William H. Childs (M) in 1983 cofounded EEsof Inc. to provide high-frequency analog design software for the engineer. He served the next 10 years as EEsof's executive vice president of product development. Since the October acquisition of EEsof by Hewlett-Packard Co., he has assumed responsibility as R&D manager of HP EEsof's Westlake Village, Calif., facility.

less data-acquisition systems has produced this sea change.

"Any wireless system will comprise some RF components and DSP," said HP senior scientist Jeremy Bunting. "You build one board with all the parts" and it keeps costs low. Of course, designers then need a software tool to handle all parts of the system on that single printed-circuit board, which is exactly what Bunting claimed his product can do. In the past year, he declared, "we launched EEsof Series IV, where we integrated all the tools under one industry-standard GUI."

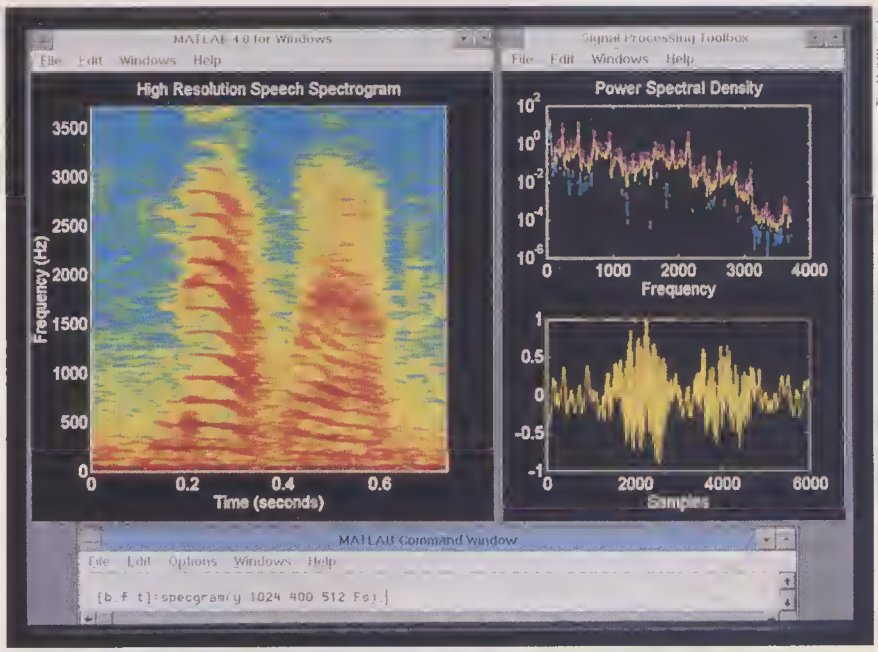
This, however, does more than handle the components themselves, since at high frequencies complex events befall physical systems. Designers working with a single board incorporating all the technologies needed for wireless applications—digital signal processing (DSP) and nonlinear RF, for starters—must be able to put their hands easily on the software tools they need.

"The technology issues are pertinent," Bunting noted. "The boards radiate, couple, and so forth. Before, people hadn't had to face this kind of problem. You have to analyze the effects of all the components on the board, and all their couplings." But the HP range of tools, built around components operated at high frequency, can cope, said Bunting. EEsof Series IV, which shipped in February and March of 1993, was built from the ground up.

Bunting agreed that the integration of the functions needed for an overall design is a continuing, industrywide trend. "Every major EDA [electronic design automation] company"—notably View Logic, Cadence, and Mentor Graphics—is "asking how to link the simulation, synthesis, layout, and testing functions into frameworks," he said. "All have digital capabilities, and all have some Spice capability for the low-frequency analog stuff."

While EEsof does not yet have a Windows version of its Series IV products, which run under Unix, the company does offer lower-level products that run under the ubiquitous GUI, and is joining the herd bringing high-level products to it. HP has a port to Windows NT in the works. Release 6.0 will ship in the third quarter of 1994, and it will be the entire Unix suite on NT.

SMALL MARKET BUT GROWING. Sales of electronic-engineering and scientific applications software are, of course, only a small portion of the total of all software applications sold throughout the world. Such software is limited in function to statistical analysis, design tools of one form or another, and mathematical packages and the like. This represents only a handful of application areas compared, for example, with the vast number of, say, general-purpose productivity software packages. Moreover, the universe of scientists and engineers is a relatively stable one; while there are constant additions to the number of people using engineering tools, the number of those additions is relatively small.



The MathWorks Inc.

Being able to visualize numeric results is an important feature in a lot of new application software. Here MatLab 4.0 for Windows has produced a color spectrogram [left] of the signal shown in the lower right-hand window.

A market that serves a small universe of electronics engineers and scientific investigators might seem bound to stagnate. Yet that seems not to be happening. Hardware vendors see that their average selling prices are falling, but revenues are climbing at single-digit rates.

A look at the numbers indicates that unit sales are increasing at a rate of more than 10 percent per annum, a development clearly fueled by silicon technology advances that permit workstations and personal computers to do more for less money. As the silicon makers provide greater and faster computational power, they are also ratcheting up their own efforts to blaze the way into a new generation of silicon products. That will, in turn, propel an improvement in the tools for designing them and lead to the next generation of software products.

A constantly renewing market is how David Chen described it."You have to be able to ride the next [technology] curve, or slug it out on an existing curve," said the vice president of marketing at Mentor Graphics Corp., Wilsonville, Ore. "We are emerging into a market where the structure is changing—where the identity of the players will be different. Small technology companies have poor distribution, while the large companies and system integrators create the technology, which could be a combination of several vendors' technologies."

BREAKING DOWN. As new hardware is made available in the form of new and more powerful workstations, the software that runs on those workstations, which include personal computers with new processors and operating systems, must also improve. Soon, in fact, the software tool comes to be seen as inadequate to the task that must be performed, even though it may have been perfectly competent only a few years before.

Every five years or so, as technology improves, the tools break down, Chen argued. That is happening now with the new microprocessors, such as the PowerPC, the Alpha, and the Pentium, and with such new operating systems as NT, all of which require new software to take advantage of their varied capabilities.

"The new processors and the operating systems will impact how businesses are run," predicted Chen. While customers want to give engineers universal access to data, he noted that today many environments are not networked, an obstacle that he believes will be overcome with newer, lower-cost technology—along with the new software tools.

"The PowerPC will be in low-cost RISC workstations, whose technology and cost curves will give people the opportunity to use exactly the one they are looking for," said the Mentor Graphics executive. The consequence is an increased need for data management and integration, either internal or external.

Silicon Graphics is one company that believes in providing its workstations with networking capabilities. The company has most recently introduced a system called In Person, which includes multimedia hardware and a charge-coupled-device (CCD) camera; the arrangement allows engineers working on the same project in different locations to hold videoconferences, said marketing manager Doug Dennis. The multimedia software makes it possible to annotate design or numerical documents with voice or graphical overlays, or even with video.

But if the tools are breaking down, there is much to be done. Software and hardware companies must again invent another generation of systems. ◆

Large computers

Massively parallel-processing computer architectures were legitimized last year when IBM Corp. and Cray Research Inc. both introduced their first such systems after resisting the trend for years. An August announcement that the nation's No. 2 mainframe vendor, Unisys, would work with Intel to develop such systems allayed any surviving doubts about where the industry was heading.

Indeed, the Minneapolis, Minn.–based Smaby Group projected that, in 1993, scalable/parallel systems would have nearly as much market clout as vector/scalar machines in high-performance computing. It saw shipments rising 28 percent to US $1.09 billion even as vector/scalar systems contracted slightly, to $1.19 billion.

"Absolutely every computer company in the world agrees that parallel processing is the future, especially at the high end," said Henry Burkhardt III, president of massively parallel-processing (MPP) vendor Kendall Square Research Corp., in Waltham, Mass. "They all have parallel machines, or plans for parallel machines, or alliances that would lead to parallel machines."

STARTING SMALL. The MPP with the momentum was not the system stringing together thousands of processors for purely parallel applications, but the smaller, more cost-justifiable system that could be scaled up as it proved its worth in production environments. In fact, systems that mixed MPP and vector capabilities were selling well.

IBM and Cray Research, for instance, bowed to the inevitable with hybrid systems. These represented carefully hedged responses to their customers' demand for MPP's price/performance improvements. At both companies, executives still cautioned that many current MPP installations, with only 16 or 32 processors, do not live up to what proponents have promised in production environments.

"There's still a lot of confusion in the market," said Robert Ewald, general manager for supercomputer operations at Eagan, Minn.-based Cray Research. "With RISC-based systems there's a cutoff point, somewhere in the 32- to 64-processor range, below which their distributed memory systems demand too much in the way of applications conversion and memory management for production settings. Below that point, physically shared memory systems, such as multiprocessor workstations or high-end servers, do better."

Cray's T3D, promised 26 months earlier, was delivered in September on time and with nine orders from customers in hand. The system, jointly developed with the Advanced Research Projects Agency (ARPA), scales from 32 reduced–instruction-set computing (RISC) microprocessors to 2048 of them.

Citing studies that faulted existing MPP systems for imbalance among their processors, interconnects, and input/output systems, Cray officials said they had sought a finely tuned system blending the best of vector processing and MPP. Off-the-shelf Alpha microprocessors from Digital Equipment Corp., based in Maynard, Mass., form the basis for the MPP compute nodes of the T3D, but circuits used in the I/O and interconnect systems are based on those of Cray's conventional Y-MP and C90 supercomputer models. The torus-like configuration of the MPP section minimizes internodal distances and hence communication delays.

The fruits are some impressive capabilities. The parallel side was closely coupled to the vector computer through one or more bidirectional I/O channels, each with a bandwidth of 400 MB/s. System memory access latency was in the microsecond range, or a claimed 1/100 that of many competing systems.

The machines are not cheap. Attached to a customer's existing Cray, a 32-processor T3D starts at $2.2 million, while stand-alone, single-cabinet systems start at $7.7 million. Even so, "We think the T3D will bring us from zero to first place in MPP market share in just one year," predicted company chairman John Carlson.

WILD CARD. IBM's 9076 SP1 came as more of a wild card than the T3D, which Cray Research officials had been describing for more than two years. It debuted in February as one element of a three-pronged push to reduce high-end computing costs. The other two prongs were continued enhancements to the ES/9000 line, including a family-wide transition to CMOS processors, and another parallel computing effort, using microprocessors based on the S/390 processors of the mainframe line. Despite their earlier silence, IBM officials said these efforts were intensive.

"This is the path of a number of years, but it perhaps has become more urgent in the past year as the price advantages of alternative platforms have become more apparent and as the right-sizing trend among customers has accelerated," said Bill Reedy, director of market operations at IBM's Large Scale Computing Division, Fishkill, N.Y.

The SP1 was presented as a real-world machine: customers can run day-to-day serial production work on a single node even as they experiment with parallel applications. It is scalable from eight up to 64 of the Power microprocessors that drive IBM's RISC System/6000 workstation line.

The system, targeted at numerically intensive computing applications, could be configured with one to four "frames," each housing eight to 16 processor nodes and a redundant power supply. An optional high-performance switch supports the internode communications essential to parallel applications—and, with a bandwidth said to scale linearly to thousands of nodes, is to be the basis for future MPP systems. The peak performance of each node was claimed at 125 million floating-point operations per second (megaflops). Commercially oriented systems running popular relational database management systems were to follow early this year, as well as updated hardware employing the second-generation Power2 chip set that arrived last fall.

Both the IBM and Cray machines were generally available by late last year. The Unisys system, in contrast, will not come to market until 1995. Nevertheless, for an established mainframe vendor long doubtful of parallel system reliability, to make that announcement in August seemed proof enough that commercial viability is not far off.

The Blue Bell, Pa., company allied itself with established MPP vendor Intel Corp. of Santa Clara, Calif., whose Supercomputer Systems Division has sold RISC-based Paragon machines to scientific and technical users. In contrast, the new system will employ the complex–instruction-set computing Intel CISC line to which Unisys in late 1991 had shifted its Unix development.

Intel's new-generation Pentium microprocessor will power the system's computing nodes, which will communicate at high speed over the mesh interconnect subsystem

HIGHLIGHTS

- **NCR takes on new competition**
- **Parallel unit wins airline reservation bid**
- **IBM's parallel processor debuts**
- **CEOs spin through revolving door**

Gerry Khermouch Contributing Editor

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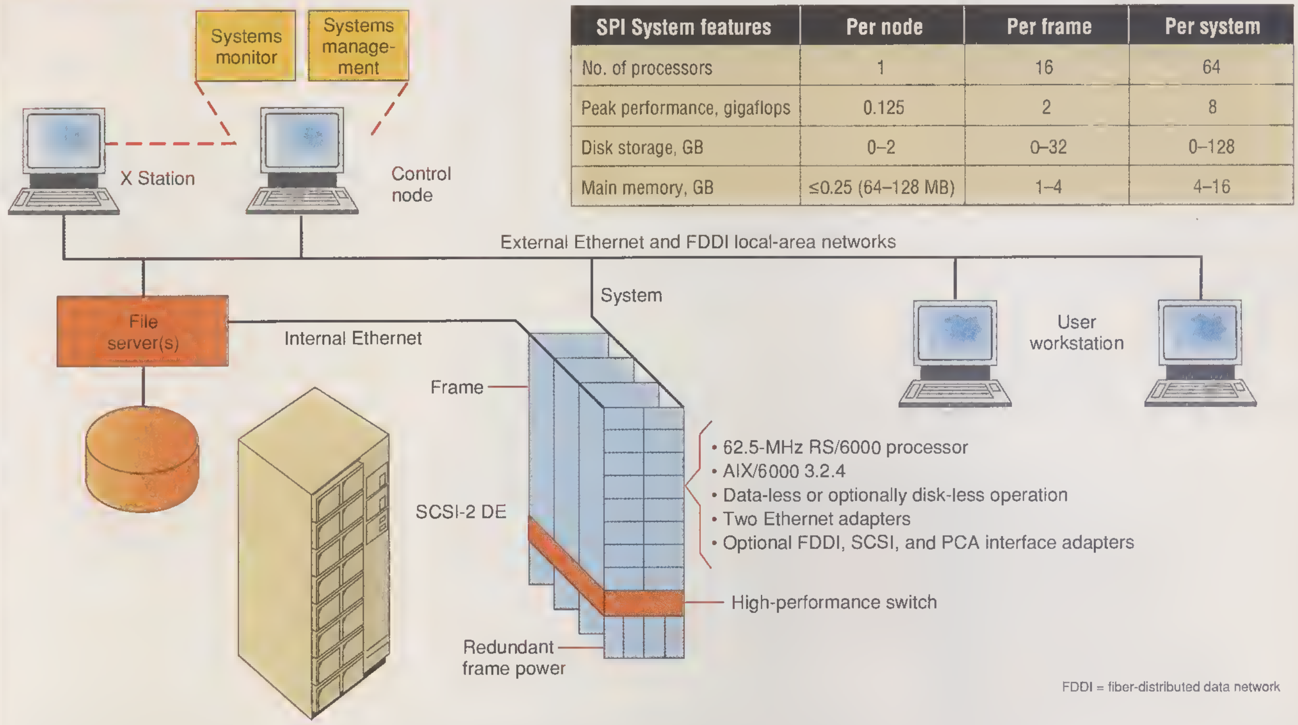
SPI System overview

SPI System features	Per node	Per frame	Per system
No. of processors	1	16	64
Peak performance, gigaflops	0.125	2	8
Disk storage, GB	0–2	0–32	0–128
Main memory, GB	≤0.25 (64–128 MB)	1–4	4–16



IBM Corp.'s 9076 SP1 parallel computer supports a mix of serial production work and parallel applications. The machine is based on the company's Power RISC processor, which is slated to play a role in IBM products ranging all the way from portables to supercomputers. A separate parallel-processing effort has its roots in IBM's S/390 mainframe processor.

used in the Paragon line. Message traffic, at 175 MB/s in each direction, is managed by separate submicrometer router chips. Unisys is co-designing the node boards and I/O systems and contributing its advanced implementation of Unix.

GOING COMMERCIAL. The sober air of realism about the IBM and Cray Research parallel systems was caused not only by the huge installed constituencies that would depend on them for a smooth upgrade path, but also by the sluggish economy that had turned users off making major capital investments—whether in MPP systems, vector processing supercomputers, or even mainframes. In that climate, users were demanding production-hardened units that could begin earning a return on investment at once.

At the high end, this attitude played to the strength of several vendors who had targeted commercial applications. Notable among these was AT&T Corp.'s NCR unit and its recently acquired Teradata unit. Long dominant in decision-support systems, the unit was looking to augment its presence in the more exacting area of on-line transaction processing (OLTP).

NCR went on merging Teradata's DBC/1012 line with its internally developed NCR 3600 system, which mates a front-end, general-purpose system with a back-end database engine based on Teradata technology. Significant commercial business came in from customers like U S West Inc., and a two-year delay in introducing the next-generation NCR 3700 seemed to be offset by the fact that few NCR 3600 customers were pushing the limits of that system yet.

But competition was mounting. "Teradata killer" was the name in some circles of a parallel-based accessory to its mainframes that IBM was readying for delivery early this year. Tandem Computers Inc., Cupertino, Calif., unveiled its highly scalable Himalaya line. Convex Computer Corp., Richardson, Texas, stepped up its collaboration with commercial systems powerhouse Hewlett-Packard Co. of Palo Alto, Calif., broadening the application base of Convex' parallel machines. Existing lines from Thinking Machines Corp. and Kendall Square Research won big commercial orders, for both private-sector technical and general-business applications.

Thinking Machines' sale of a 128-node Connection Machine CM-5 to Mobil Corp. for seismic processing was regarded by Gartner Group's director of high-performance computing, Howard Richmond, as the industry's most significant in years. It needed only 10 days and $100 000 to do a job that took 29 weeks and $2.8 million on a Cray Research Y-MP vector machine, and it epitomized the strategic gains of targeted MPP use. "The rest of the industry will be hard-pressed to catch up," Richmond said.

With an order from American Airlines' parent, AMR Corp., Kendall Square symbolically moved an MPP system into a glass house inhabited by the ultimate in mission-critical, on-line transaction-processing systems from IBM: the Sabre airline reservation network. Kendall Square's 64-processor KSR1 system was merely to assist in sifting through the oceans of data generated by Sabre, but as officials made clear, AMR would be evaluating the technology for its future migration from conventional mainframes. Competitors complained that Kendall Square was low-bidding its way into such business, and in December, Burkhardt relinquished his chief executive's duties as the firm came under fire for, among other things, aggressive revenue-booking policies. Even so, the fact that an MPP had breached the walls of this particular glass house seemed promising to all vendors.

FALLEN WALL. Last year, for the first time, general-business applications attracted supercomputer vendors other than IBM and NCR, whose voice had seldom been heard outside scientific and technical precincts. Why? In part, as a matter of sheer market potential, given the erosion in user loyalty to the mainframe. Gartner's Richmond expects commercial jobs to account for 70 percent of MPP business by 1997. With such entirely new applications as video on demand enticing such entrants as IBM and nCube Corp., few observers would dismiss that projection as outlandish.

Some observers also traced the interest to the fall of the Berlin Wall—and the accompanying shift in priorities at U.S. government agencies. "Until the collapse of the Evil Empire, price was no object in certain Federal agencies where demand for machines priced in the tens of millions was concerned," Smaby said.

ARPA, for one, announced that from now on it would shift much of its support to soft-

ware development. And funded programs—say, the National Science Foundation's supercomputing centers—were being tied to timetables for transferring technical advances to the private sector. Since about 90 percent of MPP systems were funded to some degree by the government, such shifts were sure to get supercomputer vendors' attention.

"What taxpayer-supported, government laboratories do is far less relevant than the ability to use this technology in commercially oriented, profit-making applications," declared Gartner's Richmond.

WE AIM TO SERVE. As mainframes and midrange systems came under greater assault last year from CMOS-based workstations and multiprocessors, IBM and Digital Equipment launched a Herculean effort to reposition their authoritarian central processors of old as avuncular servers in enterprise-wide client-server networks. This way, "users can take advantage of disk space that's larger than what's in the glass house," said IBM's Reedy.

Digital Equipment brought out the second generation of its Alpha AXP server line—and more than 150 other products and services—as part of a move to what it called open client-server computing.

New machines in the DEC 2000, 3000, and 4000 lines were positioned as entry-level, work group, and distributed-computing servers, respectively. Toward the high end, the DEC 7000 AXP data center servers offered up to six-way symmetric multiprocessing and a maximum I/O bandwidth of 400 MB/s.

IBM sought to redefine both its mainframe and midrange offerings as servers. Rolling out 18 new mainframe models, including an eight-way unit, it introduced software allowing the mainframes to act as "superfast, large-scale file servers"—say, for workstations linked together in Novell Netware local-area networks.

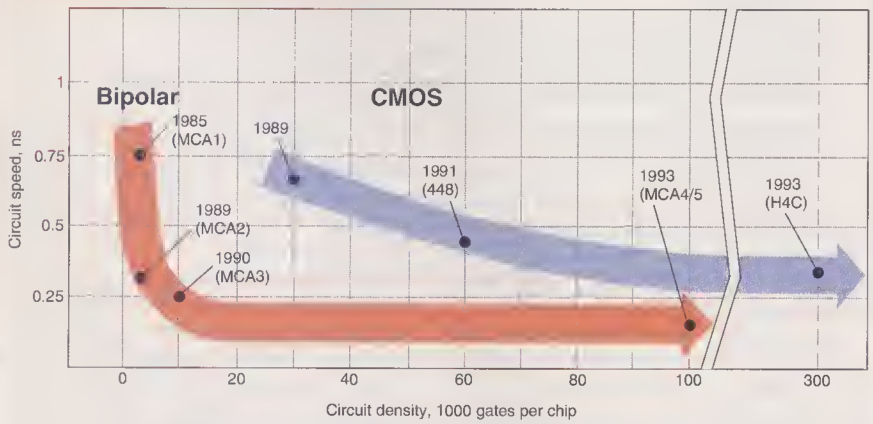
In debuting its Server Series of AS/400 midrange machines, IBM likewise said future AS/400 software development would focus on client-server applicability. Elements of the OS/400 operating system would be redesigned to improve file server functions, and performance of the APPC and TCP/IP communications protocols upgraded. "The environment has evolved to networks of connected servers," explained general manager John Thompson, soon to become group executive of the Large Scale Computing Division. "Our vision is to make the AS/400 the server of choice for many customers."

TIME TO SCRAMBLE. No better example of the tough business climate could be found than the spectacle in late 1992 and early 1993 of two supercomputer pioneers—Seymour Cray and Steve Chen—both scrambling for new investors in their troubled development efforts. After Cray Computer Corp. logged two consecutive years of losses in the $50 million range, Seymour Cray managed to lend a four-processor version of his gallium-arsenide-based Cray-3 machine to a national laboratory while trying to continue work on the successor Cray-4. But long-term prospects for the Colorado Springs, Colo., company were uncertain.

Chen's money chase followed IBM's withdrawal of support for Supercomputer Systems Inc. (SSI). The secretive Eau Claire, Wis., firm was aiming for a 32-processor system that could exceed 51 billion calculations per second, but five years and perhaps $200 million had yielded a four-processor prototype at best. Unable to round up the $60 million he needed, Chen moved on to a new and presumably more modest development effort, SuperComputers International. Some undisclosed technologies were acquired from SSI by Cray Research.

A couple of years earlier, both might have found investors. In 1993, though, they were out of date, still relying on vector-processing concepts when sentiment was shifting to MPP. Worse, both had already gorged on cash without proving their systems' commercial viability. Amid the industry's chilly pragmatism, prospects were poor for the two pioneers.

Component technology trends



Note: serial numbers are internal Unisys designations for processors used in its machines.

With CMOS processors approaching the circuit speeds of bipolar chips, Unisys Corp. unveiled its first CMOS-based mainframe, the 2200/500. Shown here are the performance characteristics of successive generations of bipolar and CMOS chips used in Unisys products.

Even established MPP vendors struggled. To control costs and seek out commercial customers, Thinking Machines installed an attorney as president, then forced out cofounder Sheryl Handler as chief executive—all in a year when the Cambridge, Mass., firm bagged major commercial business (including the Mobil job) and saw its Connection Machine star in the blockbuster film *Jurassic Park*!

Mainframe builder Amdahl Corp. last year had endured three layoffs by fall, and scrapped development of enterprise and work group servers based on Sun Microsystems' Sparc line of RISC microprocessors; development of Sparc-based MPP systems, though, was expected to continue. In France, the government prepared to pump another $1.5 billion into troubled Groupe Bull and installed a new chief executive to prepare the state-owned company for privatization. In Britain, though, Fujitsu-controlled ICL was readying a parallel database server based on Fujitsu CMOS chips; it would integrate with an installed base numbering in the thousands.

As for the Japanese, after investing their way out of previous economic downturns, they hit what turned out to be the worst slump since World War II. The outlook was bleakest for makers of IBM-compatible mainframes. "Fujitsu and Hitachi are wringing their hands," said Gartner's Richmond. "Making 390-type machines is a dead end." Early in the year, Mitsubishi Electric Co. ended its development of mainframes. The company said it will go on selling its EX800 line, but not develop a successor.

Even affirmative commitments in Japan were hedged. NEC Corp. started marketing a parallel computer, Cenju-3, but styled it merely a software development unit anticipating larger units. High-end units, due to start shipping overseas in early 1994, employed 256 processors to achieve 12.8-gigaflops performance. Fujitsu began a push into parallel processing with narrow, application-specific computers.

NO MOSS ON CMOS. The jolts on the business side contrasted starkly with the smooth progress on the technology side. Bipolar, emitter-coupled logic technology continued to lose ground to CMOS technology as high-end systems vendors prepared to ditch expensive, water-cooled machines. In 1993, Unisys began the transition with a mainframe line, the 2200/500, that needed just 18 CMOS chips for its central processing unit, versus 197 ECL chips for the 2200/900. The new unit, which debuted in September, started at just $350 000—a minicomputer price.

Inexpensive CMOS technology also lowered the barriers to entry to the market. One unexpected entrant was Thinking Machines' co-star in *Jurassic Park*, Silicon Graphics Inc. The workstation builder said it would make a run at the supercomputer market with RISC-based machines called Power Challenge; starting price is under $1 million. A 5-gigaflops machine based on a superscalar RISC processor developed in-house was to

BURKHARDT: The smoke is clearing, and parallel processing has won

VIEWPOINT

Only a year ago, two open-minded individuals could have legitimately differed on the timing of parallel-processing systems' entry into the computing mainstream. Now, at the start of 1994, there no longer can be any serious debate on the issue. Standards-based parallel processing is robust, it is desperately needed, and it is here to stay. Users are demanding it, and vendors who think they have two, three, or four years to deliver will be in for a rude awakening.

Why? Consider it from the user's perspective. Whether in a laboratory or a bank's glass house, users are facing organizational and competitive challenges as never before. International competition, deregulation, the end of the Cold War, and the reengineering of most work have placed intense pressures on costs, flexibility, and turnaround times. Researchers are learning to collaborate despite widely separated locations. Commercial users, needing access to on-line information from a diverse array of sources, are balking at taking another step into the proprietary swamp.

As a consequence, both groups are demanding standards, standards, standards—in the operating system, tools, applications, interfaces, databases, and interconnects.

At the same time, users are running databases of unprecedented scope. Whether scientific data generated from satellites in space or financial data generated from the trading floor, they all add up to new database requirements.

Scientific and technical as well as commercial data-processing users have a common goal: the need to find solutions to larger and more complex problems in ever shorter times. Information technology based on very high-performance computing systems is now recognized by leading-edge users as delivering a clear competitive advantage.

That has not gone unnoticed by the vendor community: by the end of 1993, every major U.S. vendor had jumped into parallel processing with a paper relationship, a paper product, or an actual product launch. Virtually all suppliers of mainframes announced shifts away from bipolar circuits with expensive packaging toward CMOS systems using lower-cost packaging. IBM began the painful process of reducing staff and facilities in its major production complexes along the Hudson River and announced a CMOS version of its new 390 architecture.

The arguments about parallel systems are essentially over: they offer much higher performance and lower costs of computing. And the smoke is beginning to clear from the architecture war: with few exceptions, architectural techniques such as single-instruction, multiple-data (SIMD) and message passing have barely moved out of the computer science laboratories. Standards-based, symmetric multiprocessing with a shared memory has won.

'Vendors who think they have two, three, or four years to deliver a standards-based, symmetric parallel processor will be in for a rude awakening'

Meanwhile, the user profile is changing. Both industry analysts and established vendors were stunned at the depth of customer dissatisfaction with their computer vendors and at how quickly users were willing to look at alternative solutions such as workstation clusters or new products from relative newcomers. But they should have seen it coming.

Scientific and engineering users were under growing pressure to simulate the real world rather than incur the time, risk, and expense of doing physical experiments. More chemists moved from the wet bench to the computer screen. Fewer automotive engineers were allowed the luxury of building automobile prototypes to crash-test; designs had to be simulated on a computer.

Fewer users were computer specialists. More commonly, they were scientists or engineers whose goal was to get the work done without standing in line waiting for applications to run in batches on a supercomputer. In frustration, they turned to idle workstations at night and on weekends. As they learned to cluster workstations to get work throughput, they began to erode the supercomputer market and its traditional profit margins. High-performance, high-throughput tasks remained the province of scalable, shared-memory multiprocessors and vector supercomputers, but other tasks migrated rapidly to alternative computing platforms.

Among commercial data-processing users, the change seemed even more dramatic in 1993. No longer was that user typically an accountant or chief financial officer looking for ways to save money and eliminate labor. More often, it was a business, sales, or marketing visionary looking for ways to make money with technology. Commercial organizations ranging from financial services and telecommunications to airlines and packaged goods were designing new delivery, monitoring, and marketing systems that were far more centered on the customer. These systems require the extraordinary amounts of computing power that are now becoming available, at affordable prices, from the new standards-based parallel-processing systems.

Henry Burkhardt III (M) is president and co-founder of Kendall Square Research Corp., a publicly held vendor of high-performance parallel computing systems based in Waltham, Mass. He began his career in 1964 as a programmer at Digital Equipment Corp., and went on to co-found Data General Corp. in 1968 and Encore Computer Corp. in 1982.

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ship early in 1994, with a 1-gigaflops desktop system to follow in 1996, the company said.

MAKEOVER AT IBM. In 1993, IBM finally jumped on the bandwagon. Although years of organizational tinkering have sometimes made it seem that IBM stands for "I'm Being Made-over," last year the changes proved more decisive and more fruitful. They culminated, of course, in the bringing in of an outsider, RJR Nabisco's Louis V. Gerstner Jr., to run the company. Gerstner downplayed any immediate need for a cosmic "vision" for IBM in favor of an emphasis on execution, and there were signs the tinkering was paying off.

Take the SP1: it was delivered by an internal joint venture, Power Parallel Systems, an independent business unit that combined the development resources of the mainframe and workstation organizations. Analysts said it showed IBM was dealing more effectively with the internal schism between the Hudson Valley development heartland for vector mainframes and the Austin, Texas, development seat for the insurgent breed of RISC-based microprocessors.

Given their similar migrations toward CMOS and a client-server role, Gerstner put midrange and enterprise-level systems under one roof headed by former midrange chief Thompson, again to encourage technology sharing. And with Power systems proponent James Cannavino stepping up in November to IBM's chief strategic post, there was speculation IBM would accelerate its reliance on the processor and its 64-bit derivative under development by IBM, Apple Computer, and Motorola.

The extent to which the Silicon Prairie group in Austin is driving development was clear in September, when it unveiled the eight-chip Power2 processor, supporting over 500 000 operations per second. "We're clearly into the supercomputer level of performance," said Phil Hester, vice president of systems and technology for the Advanced Workstations and Systems group. The U.S. Department of Commerce seemed to agree: it looked at the new midrange PowerServer 590, based on the chip set and priced around $75 000, and awarded it the special export license reserved for supercomputers. ◆

Solid state

Competition among semiconductor manufacturers has intensified, quickening the pace of technological development. In the drive to capture market share, companies are turning out new generations of products with dizzying speed. Sub-half-micrometer lithographic feature sizes in commercial products have pegged new lows, while 275-MHz processing speeds have reached new highs. With feature sizes hurtling toward 0.25 μm, scientists are optimizing everything from process-monitoring software to circuit boards and modules. Some are already looking at the next step—linewidths of 0.18 μm and below—that will be needed to make 1-gigabit memories.

To keep up with product demand and rapidly advancing technology, new factories are going up all over the world, and marketing strategies have changed. Systems manufacturers now sell products that were originally intended for internal use. IBM Corp. now sells everything from chips to computer-aided-design (CAD) tools to regain profitability.

The advances in silicon fabrication techniques have spilled over into other areas, particularly the ability to produce micromachines on silicon substrates. And applications of such alternative technologies as silicon-germanium heterojunction bipolar transistors continue to rack up successes at frequencies beyond the range of simple silicon devices.

CHIP DESIGNS ADVANCE. Microprocessors were one of the most fiercely contested areas last year [see "Not your father's CPU," *IEEE Spectrum*, December 1993, pp. 20–23]. In March, Intel Corp., Santa Clara, Calif., announced the Pentium chip, developed with a speed that is testimony to the hot pursuit of the desktop and laptop markets by the manufacturers of reduced-instruction-set computer (RISC) chips. Pentium's designers faced a daunting assignment: developing a new architecture with enhanced performance competitive with RISC designs, yet also maintaining backward compatibility with the large installed base of 486 chips. This they accomplished by pulling in such advanced features as superscalar operation, dynamic branch prediction, and a pipelined floating-point unit.

One reason for Pentium's urgency may have been the PowerPC 601, developed by IBM, Motorola, and Apple Computer and announced last April. This RISC design borrows heavily from IBM's Power architecture and Motorola's 88110 bus interface design. The 601 outperforms and under-prices the Pentium, but to be successful it must build up its selection of software applications.

Advanced as they are, Pentium and the PowerPC 601 have not outclassed the Alpha 21064 microprocessor, announced by Digital Equipment Corp., Maynard, Mass., in 1992 [see "How DEC developed Alpha," *Spectrum*, July 1992, pp. 26–31]. Now, DEC has announced a new chip meant for the desktop. Like the 21064, it is based on the Alpha architecture, but adds such capabilities as an embedded graphics accelerator and a peripheral chip interconnect (PCI) input/output controller that are especially attractive for desktop and multimedia applications.

GREEN MACHINES. Spurred by the increasing popularity of portable computing and communication devices, reductions in the operating power and voltage of IC circuits were recurring themes this year. Many microprocessors, application-specific ICs (ASICs), and memory chips are now designed to run at 3.3 V, halving power consumption. A number of microprocessors have also incorporated sleep, doze, or nap modes that power off their circuits when the machines are idle, reducing power to a few milliwatts.

Intel's entire 486 product line, as well as the Pentium chip, have power management capability. The feature is also available in Toshiba Corp.'s R4600, a new 64-bit RISC chip, and in the PowerPC 603, the IBM-Motorola-Apple follow-on to the 601 for laptop applications. Power management will enable computer manufacturers to design systems that comply with the U.S. Environmental Protection Agency's voluntary Energy Star Computer Program. The program's aim is desktop computers that have a low-power state of not more than 30 W when idle, compared with the more than 200 W that current units soak up. Desktop units now account for 5 percent of the United States' energy consumption.

When it comes to performance, IBM's Power2 processor currently enjoys the lead, with industry benchmark ratings of 126 SPECint92 for integer and 260 SPECfp92 for floating-point performance. (The benchmarks are representative samples of publicly available applications that predict how well application code will execute, and also standardize performance comparisons of computing systems.) Power2's highly superscalar architecture can issue up to six instructions per cycle. This processor is composed of eight chips and 32 million transistors on a multichip module. IBM intends to keep the Power2 chip sets for its high-end workstations, which should be available early this year.

Not to be outdone, Digital Equipment announced the second-generation Alpha: the 21064A, fabricated with 0.5-μm CMOS devices. The single-chip microprocessor has been clocked at 275 MHz. If it can deliver on its estimated benchmarks of 170 SPECint92 and 290 SPECfp92, it should regain the performance lead from the Power2.

PDA HEYDAY. The appearance of personal digital assistants (PDAs) and personal intelligent communicators (PICs) in the consumer market has inspired microprocessor designs geared toward these new products. But because the features that should appeal to PDA system designers are still being decided, the chips bear little resemblance to one another except that—for the most part—they are smaller, cheaper, and lower-powered than their computer cousins. Most contain between 0.1 million and 1 million transistors—about one-third the size of the desktop microprocessors—consume between 0.1 W and 1 W, and cost between US $20 and $100. But that is where the similarities end. Products can be found with architectures of RISC, CISC, and none of the above. On-chip caches range from none to 8 kB. The number of peripheral functions also varies widely.

Many products, among them the Dragon I from Motorola Inc., Phoenix, Ariz., and General Magic Inc., Mountain View, Calif.; the SH7000 offered by Hitachi Ltd., Tokyo; the Polar chip set, designed by VLSI Technology Inc., San Jose, Calif,. and Intel; and the V810 from NEC, are ready and waiting to be picked for PDAs.

AT&T's Hobbit chip and the ARM610, from Advanced RISC Machines Ltd., Cambridge, England, are two processors used in products that came to market last year. The Hobbit, a 32-bit chip that runs at 20 MHz at

HIGHLIGHTS

- Dozing microprocessors save power
- New Alpha chip achieves 275 MHz
- Micromachines deploy airbags
- Silicon-germanium ready for market

Linda Geppert Associate Editor

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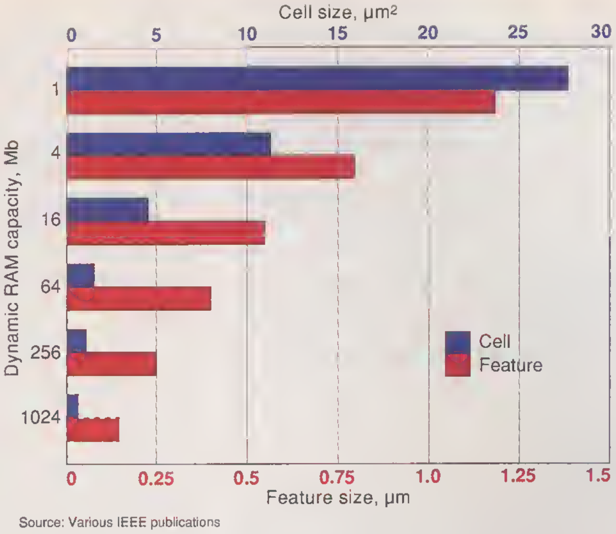


The road to 1-gigabit dynamic RAMs is paved with advanced lithographic techniques and clever cell designs that reach 0.15-μm linewidths and 0.6-μm² cell sizes.

3.3 V and consumes only 0.25 W, is used in AT&T's EO 440, a personal intelligent communicator. The ARM610 runs at 20 MHz at 5 V and consumes 0.5 W. It was tapped by Apple Computer Inc., Cupertino, Calif., for its Newton MessagePad personal digital assistant. Advanced RISC Machines' successor to the ARM610, the ARM700, can run at 3.3 V at a reduced power of 0.25 W.

In memory chips, change has been incremental and largely predictable [see figure, above]. Most manufacturers of dynamic RAMs (DRAMs) are planning for the 16-Mb chip to become the next commodity item, with the 64-Mb chip well along the road toward volume-production status. Several varieties of 256-Mb DRAMs are in the development stage. The IBM-Siemens-Toshiba joint effort is based on a 0.6-μm² trench-capacitor cell that uses a self-aligned trench-to-device contact to reduce the cell size.

IBM and Mitsubishi Electric Corp., Tokyo, have each fabricated DRAMs on silicon-on-insulator (SOI) substrates. SOI substrates offer higher-speed devices, lower junction leakage, and greater alpha-particle immunity, making their development especially desirable for DRAMs. IBM's chip is a 512-kb DRAM with a 3.5-ns access time. The Mitsubishi device is a fully functional 16-Mb DRAM.

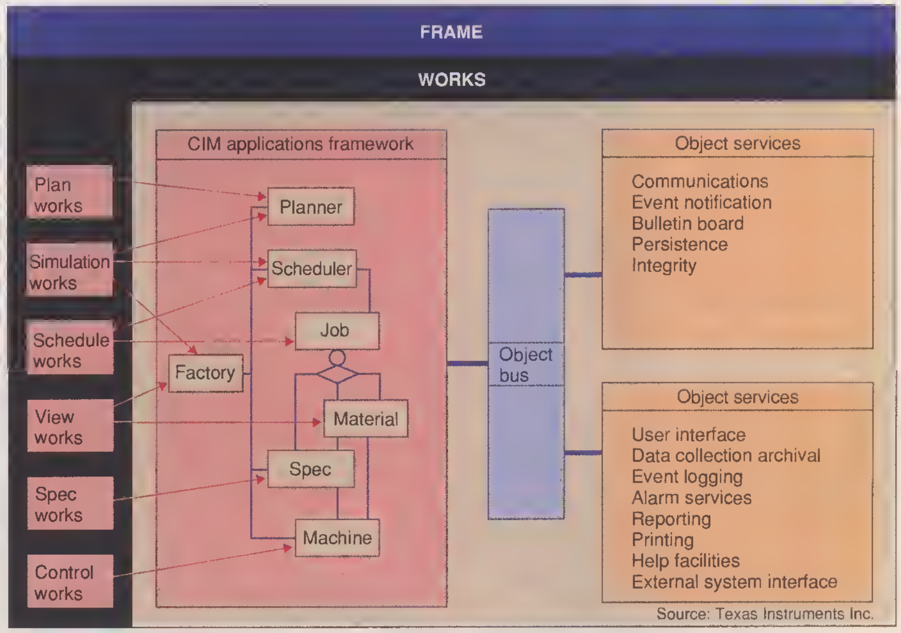
RAMBUS GETS REAL. While 1-Gb DRAMs may not appear on the market until the 21st century, clever architectures have improved the performance of existing technologies. One such innovation is the Rambus interface. It consists of conventional DRAMs with added circuitry as well as a Rambus ASIC and a specially designed printed-circuit board interconnect. This architecture can achieve data-transfer rates of 500-Mb/s with standard semiconductor and printed-circuit board technologies. It took a large step forward in 1993 with the demonstration of a system containing Toshiba Rambus 4.5-Mb DRAM (RDRAM) chips together with a Rambus ASIC (RAC). Toshiba will market the RDRAMS beginning this year. Under development at Toshiba is an 18-Mb RDRAM and RAC designed in 0.5-μm CMOS. These products should be available before the end of the year.

Driven by capacity limitations and by the need to gear up for more highly integrated processes, many semiconductor companies have announced plans to build new manufacturing plants or add to existing ones. Japanese and Korean companies are extending their DRAM facilities in anticipation of the demand for 16-Mb DRAMs. Last June, Samsung Electronics Co., Seoul, South Korea, opened a new facility to mass-produce DRAMs—up to three million a year. Toshiba Corp., Tokyo, and Motorola will jointly build a 16-Mb DRAM plant at Sendai, in northern Japan. In the United States, Intel, Motorola, and Texas Instruments Inc., Dallas, will construct new state-of-the-art facilities that will process 200-mm wafers and allot sizable areas to class-1 clean rooms. The Texas Instruments and Motorola facilities will also include development laboratories to eventually produce ICs with linewidths as small as 0.12 μm. Before the plants are completed, each of these companies will have spent close to $1 billion.

According to Bill Dunnigan, operations manager for Motorola's MOS11 chip fabrication line, "The major issue we all face is how to make money with the accelerating cost of equipment. As the technology moves from 1 μm to 0.5 μm to 0.25 μm, the number of process steps increases, requiring more and more equipment. So we need to build larger fabs. The problem is that the selling price of the devices keeps going down." The challenge, said Dunnigan, is that the costs of new equipment and of building new factories are growing faster than the revenue stream. Everyone in the industry is investigating ways to rein in the size of factories while maintaining volume production.

SMART FACTORIES. Improvements in the quality and yield of semiconductors will also come from computer-integrated manufacturing (CIM) systems that use computers and software to monitor tools and control process flow. One such system, the result of a five-year collaboration of Texas Instruments, Sematech, the Advanced Research Products Agency (ARPA), and the Air Force Wright Laboratory, is geared to flexible, or agile, manufacturing and offers the ability to plan production starts, schedule tools, and manage tool and process specifications [see figure, below]. Texas Instruments will market the software under the name Works.

Other aspects of the collaborative program include single-wafer processing; advanced dry, rapid thermal processes; in-situ sensors; and real-time embedded closed-loop process control. Under the terms of the agreement with ARPA and Sematech, these

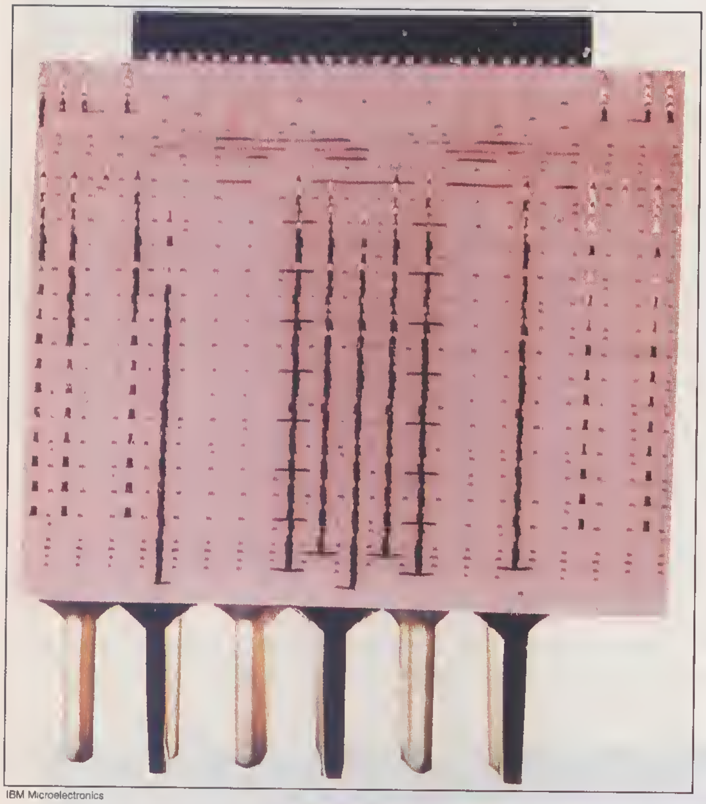


Modular integrated software from Texas Instruments Inc. allows manufacturers to track and control the production process through such services as remote object communication, logging of time-stamped events, and the specification and triggering of data collection.

tools will be made available commercially as soon as they have been developed.

With the rapid rise in IC performance and complexity, the characteristics of connections between chips are becoming more critical. In this area, multichip modules [see figure, below] have an edge, according to Bernard T. Clark, manager of packaging business development at IBM Microelectronics, East Fishkill, N.Y. "MCMs offer the ability to escape high chip I/O, provide a low-noise environment for the devices, and reduce the off-chip interconnect length." But the merits of MCMs have been less at issue than the commercial feasibility. Historically, manufacturers of mainframes have produced MCMs primarily for use in their own products; but two new commercial sources of MCMs may help the technology take off. IBM now sells co-fired-ceramic and multilayer thin-film MCMs on the merchant market, and MicroModule Systems Inc., Cupertino, Calif., offers the thin-film variety. The latter company acquired its MCM manufacturing facilities, process, and patent portfolio from Digital Equipment Corp.

MicroModule Systems believes that the most crucial element in the fate of MCMs on the merchant market is the availability of unpackaged ICs that have been tested and burned in (known good dies). Until recently, such chips were not available, and without them the costs to systems manufacturers of reworking modules to replace defective dies were simply too high. Several semiconductor manufacturers now make known good dies available to their customers. MicroModule Systems has developed a bare-die test and burn-in technology that needs no extra die processing. It is being marketed by Texas Instruments to semiconductor manufacturers, who will then make the tested dies available to systems manufacturers. The test units, currently in beta-testing, should go on sale this year. IBM makes known good dies available for chips designed for its flip-chip bonding process.



IBM Microelectronics

The thermal conduction module (TCM) holds more than 100 chips in an area of 127 cm^2. It is manufactured by IBM Corp. for mainframe computers. This polished cross section view reveals the vias running vertically, and the cross sections of wiring lines projecting into the page.

Analog Devices Inc.

The industry's first surface-micromachined accelerometer deploys automobile airbags. The sensor is at the center of the die, surrounded by signal-conditioning circuitry.

SILICON ALTERNATIVES. The first commercial products based on silicon-germanium heterojunction bipolar transistors (Si-Ge HBTs) will reach the marketplace within the year. These devices are two to three times as fast as ordinary silicon bipolar transistors, yet can be fabricated on the same wafer with standard silicon circuits. The key to the high speed of the devices is the electric field created in the base of the transistor when it is doped with germanium in a very well-defined profile. For years, IBM scientists quietly developed the technology for making the transistors—and then for making them at medium-scale-integration levels with commercial-grade yields. This is done with low-temperature ultrahigh-vacuum chemical vapor deposition (UHV/CVD), a technique developed by Bernard Meyerson, an IBM Fellow at the Thomas J. Watson Research Center in Yorktown Heights, N.Y.

"The technology is much further advanced than anyone had previously believed," Meyerson told *Spectrum*. "We've had good yields on dies with up to 30 000 transistors." Circuits are currently being fabricated on 200-mm wafers with commercial UHV/CVD equipment manufactured and marketed by Leybold AG, Hanau, Germany, under an agreement with IBM.

Also under an agreement with IBM, Analog Devices Inc., Norwood, Mass., will design and market products based on the new technology. Charles Fadel, corporate marketing manager at Analog Devices, sees the biggest applications in high-frequency analog and mixed-signal circuits—an area in which the company has much expertise. The first commercial product will be a 3000-transistor, 1-GHz, 12-bit digital-to-analog converter (DAC) that will be used in a fiber-to-the-home application. The design was directly mapped from a traditional bipolar DAC that runs at 100 MHz. Fadel also sees a big market for the new technology in such wireless communications products as personal digital assistants, digital cellular handsets, cordless phones, and wireless local-area networks that operate in frequencies up to 3 GHz—a region of the frequency spectrum where gallium arsenide devices could also be used.

ARMSTRONG: Technical challenges cloud the deep submicrometer horizon

VIEWPOINT

Progress in 1993 was sustained on many fronts in solid-state devices. Areas like silicon-on-insulator devices, high-speed analog-digital devices using silicon-germanium alloys and band-gap engineering, and large-area arrays of charge-coupled devices for increasingly sophisticated imaging applications are just a few of the areas in which progress continues.

Yet, there are several clouds on the horizon. One is the progressive transformation of IC families into commodities (dynamic RAMs being the first and clearest example). This trend in turn leads to increasingly difficult economics for mainline silicon IC development and manufacturing. Recent and projected trends show the investment necessary for a leading-edge factory to be rising substantially faster than industry revenue. This will drive changes in manufacturing strategy—for example, much greater reliance on using a given line for multiple products and even variant technologies.

The expected rapid increase in new factory costs also raises questions for the industry consortia, Sematech and the Joint European Submicron Silicon Initative (Jessi), which have focused on manufacturing tools and techniques. How much of the rapid growth in manufacturing plant costs is due to ever more sophisticated tooling? How much is due to the costs of compliance with regulations of all kinds? How much is due to costs of plant infrastructure apart from the tools per se? Perhaps it is appropriate for these consortia to focus on other aspects of manufacturing, including more definitive characterization of the relative growth rates of manufacturing investment and industry revenues.

A second, perhaps related, cloud on the horizon is the fact that, despite many generations of IC technology, the dozen or more substantial decreases in feature size with concurrent increases in density, impressive industry learning and know-how, and remarkable progress in materials and process science, it appears to be getting harder, not easier, to push the leading edge technically and scientifically in terms of density, performance, and reliability.

'Each new technology generation poses materials and process riddles different from those solved in previous generations'

Each new technology generation poses materials and process riddles different from those solved in previous generations. There are new types of contamination to worry about, and new sources of defects when the scale is shrunk. The interactions between the different materials and layers demand to be understood with ever greater sophistication. The interaction between the mechanical properties of the multilayer structures and their subsequent processing is a constant source of unpleasant surprises.

There is still "room at the bottom" as far as fundamental limits are concerned, but I believe that the gap between scientific understanding and actual engineering practice in IC process development and manufacturing is not getting smaller. For example, although materials, process, and device simulations are increasingly powerful, they have yet to make a major dent in the time it takes, or the investment required, to work out and debug next-generation technology.

Although the problems to be solved in useful process modeling and prediction are harder, the need is no less great for logic synthesis, circuit simulation, and layout tools of far greater power than those now in use if we are to continue the current pace of submicrometer technology development.

Perhaps it is time to greatly increase the collective focus on the tasks of modeling and simulation, not only in materials and processes but also in design and layout. The Semiconductor Research Corp., individual university groups, and individual firms are all hard at work here, and the potential payoff for success is greater than ever. It may well be that these areas will lend themselves to an organized cooperative attack analogous to Sematech's successful effort in manufacturing tooling.

John Armstrong (F), IBM vice president, science and technology (retired), has been at the hub of research and development at IBM Corp. for 30 years. He is the author or co-author of more than 50 papers on nuclear resonance, nonlinear optics, research management, and science policy. He is currently serving as Karl T. Compton Visiting Lecturer at the Massachusetts Institute of Technology in Cambridge.

The same techniques used to fabricate standard ICs are also creating tiny machines on silicon wafers and integrating them with the necessary electrical circuitry. One such device is an accelerometer that is used to deploy air bags in automobiles [see lower photo at left]. It is manufactured by Analog Devices with the surface micromachining technique, where polysilicon is deposited and patterned on a sacrificial oxide. The underlying oxide is then etched away, leaving a pattern of movable polysilicon plates and fixed structures whose capacitance changes as a result of acceleration. The devices, shipped to the first customer last March, became generally available in June. Richard Payne, the company's director of R&D for micromachining, sees many more uses for the miniature devices in gyroscopes, flow meters, and medical applications.

Texas Instruments' digital micromirror device (DMD), developed for optical projection systems, is also fabricated by surface micromachining [see "Mirrors on a chip," *Spectrum*, November 1993, pp. 27–31.] The micromachined layer consists of up to two million aluminum-alloy mirrors, each suspended over a static RAM memory cell. The data in the cells is used to tilt the mirrors, while light reflected from them projects an image on the screen. One source of defects has been stuck pixels, especially white ones (those stuck in the "on" position), according to Jack M. Younse, program manager in the company's Digital Imaging Venture Projects organization. But TI has confidence in the technology and is doing whatever it takes to make it a high-quality, affordable product.

NEW RESISTS SOUGHT. New lithographic tools and mask technologies must be developed in order to produce the small linewidths required for 1-Gb DRAMs and beyond. Resists for future semiconductor lithographies were identified as a gap area, according to Daniel Herr of the Semiconductor Research Center [SRC] in Research Triangle Park, N.C. "When we look forward to advanced resists needed for 0.18-μm devices and below, we realize that we need to engineer new materials and processes to meet specific performance, reliability, manufacturability, and safety criteria," said Herr.

But development of a new resist is an expensive undertaking. "It takes about $100 million," said Herr. With anticipated worldwide demand for advanced resists in volumes of drums rather than tankloads, it is difficult for individual companies to justify long-term research programs.

As a result, SRC and Sematech have pulled together five companies—IBM, Olin Ciba-Geigy, Shipley, AT&T, and Brewer Scientific—to discuss collaborative opportunities. The participants are exploring areas where they might work together. In parallel, SRC is bringing together the top university researchers working in the resist area; joint support of university research into next-generation resists may be the most fruitful form of collaboration that these companies can undertake.

SRC supports research across the spectrum of semiconductor technology, from contamination control to metrology to packaging. Cluster tools (small, self-contained environments for film deposition) are getting a big push from SRC through funding of a development program at North Carolina State University. At the University of Illinois, modeling of cluster-tool geometries and plasma chemistry is also being supported. Such long-term research is needed as semiconductor technology is brought along into the 21st century. ◆

Test and measurement

The test and measurement industry today is at a watershed. Although the communications test market remains strong, the military-aerospace sector is in retreat, and the computer marketplace is laboring under tremendous economic pressure. Put otherwise, two of the industry's three biggest markets will offer few opportunities for growth in the years ahead, and may even decline. Instrumentation companies, in consequence, find themselves challenged by a need to redefine themselves—not just to compete more effectively in tomorrow's marketplace, but in some cases, to survive.

At the same time, certain key areas, like design for testability and computer-controlled multivendor instrument systems, have entered the implementation stage where the emphasis is more on hammering out cooperative arrangements and standards agreements than on creating new technical concepts.

Given that environment, it is hardly surprising that purely technical advances have taken a back seat to other kinds of developments—specifically, the formation of various alliances and consortia to share costs wherever it is practicable, and the application of existing technology to new areas.

In their efforts to increase revenues, some large instrument makers are rethinking their attitude toward low-end standalone instruments, which some of them have neglected for several years.

For their part, providers of hardware and software for automated calibration are taking advantage of the upcoming requirement that manufacturing companies conform to ISO 9000 if they want to do business with the European Union (formerly Community). Doing so will require, among many other things, that documented procedures for calibrating measuring instruments be developed and adhered to—a natural application for automated calibration if ever there was one.

TESTABILITY MOVES AHEAD. Ever since surface-mounted devices, with their attendant pin-access problems, began to catch on in the late '70s, the issue of testability has received a great deal of attention. Much time and talk have gone into discussions of how best to test boards and systems crammed with high-density integrated circuits. But it wasn't until 1985, when the combination of tight pin spacings and unprecedented circuit densities pressed their collective back to the wall, that a few European test engineers began work on a standardized implementation of boundary-scan testing. In 1990 the *ad hoc* body, which had become known as the Joint Test Action Group (JTAG), saw its efforts to develop an effective method for testing digital logic boards come to fruition with the approval of ANSI/IEEE Std. 1149.1, IEEE Standard Test Access Port and Boundary-Scan Architecture.

Michael J. Riezenman Senior Editor

In the short time between approval of the standard and September of 1993, 24 semiconductor companies have come out with 124 standard parts to support it, 20 vendors have developed boundary-scan ASIC cells, six are providing field-programmable gate array support, 19 firms are offering support tools, and 12 companies are including boundary-scan capability in their CAD products.

Boundary scan simplifies the testing of both chips and boards by providing for the insertion into integrated circuits of a small amount of logic circuitry, called a boundary-scan cell, between each pin on the IC and the on-chip circuitry to which each pin is normally connected. The standard also describes a test access port of four or (optionally) five extra pins, through which an external tester can control and communicate with the test features built into the compliant chip [see figure, top right].

Briefly, since boundary-scan components can be daisy-chained, all of them can be tested from a single edge connector, regardless of the complexity of the board or the chips. Maximizing the efficiency with which a chip is tested requires more than gaining access to it, however. Specifically, it requires that the chips also have built-in test (BIT) features, which can be invoked through the test access port.

HIGHLIGHTS

- **IC makers jump on the 1149.1 bandwagon**
- **ISO 9000 boosts automated calibration**
- **VXIplug&play Systems Alliance formed**
- **Huge automotive market may beckon**

So, to increase the value of their investments in boundary scan, test engineers are now looking to push test standardization further by developing and agreeing to consistent ways to implement BIT for the various subassemblies of which modern electronic systems are composed. At the 1993 International Test Conference in October, Colin Maunder, technical group leader at BT Laboratories, Ipswich, UK, who chaired the 1149.1 working group during the development of the standard, delivered a paper that may well herald the next big move in designing for testability—a concept that he calls "managed built-in test."

Managed BIT concerns itself with the real-world problem of testing systems that are produced over considerable periods of time and comprise component parts from various vendors. As Maunder points out, a big problem with testing such systems is that they are not all identical. Quite the contrary, in fact.

Over time, the components (ICs, circuit boards, subassemblies, and so on) that make up the systems may go through a series of revisions for any of several reasons, among which Maunder cited cost reduction, bug fixing, and the need to respond to problems in the supply of components. Moreover, once systems are deployed in the field, each will have its own history of maintenance and repair, as a result of which, he said, "...every fielded system will become structurally unique—that is, entropy will take place, with order degenerating into chaos as far as test engineering and field service are concerned."

How is one to test such systems, given that thorough testing generally requires detailed knowledge of how each system is implemented? With managed BIT, which differs from conventional BIT in two ways: first, it uses a standardized test interface for control and observation of the BIT functionality on each component or subsystem; and second, it employs a standardized set of core BIT functions.

With the standardized test interface, a system-level test program would send test "requests" to a test management unit on each component of the system under test. A request would not be a detailed set of instructions on how to perform a test, but rather an order to answer a question like "Are you free of faults?" It would be up to the test management unit to activate the relevant on-board BIT features needed to respond to the test request.

Will managed BIT prove to be the framework within which future standards are developed? That remains to be seen, of course; but since it is based largely on the published

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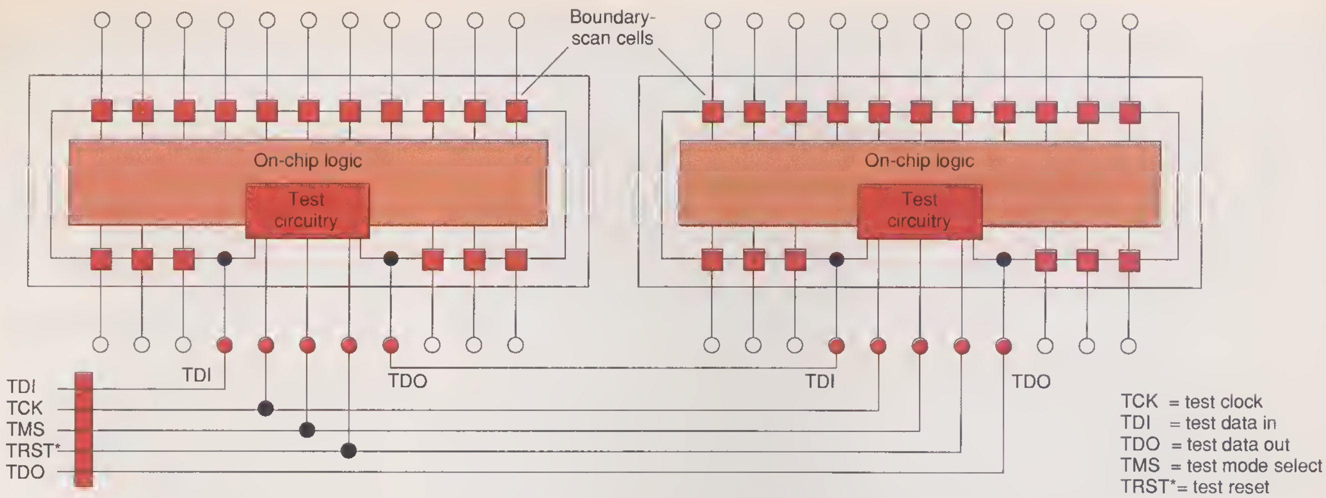


Boundary-scan cells around the periphery of a chip can be daisy-chained to make a whole board easily testable from a single access port, with no need for bed-of-nails probing. In normal operation, the cells are connected straight through—that is, each connects one of the device's pins to its intended connection point.

work of experts in the field, the odds are not at all bad.

Among the other cooperative endeavors on the design-for-testability front in recent months was the continuing cooperation among Tektronix, Teradyne, and Texas Instruments to develop boundary-scan products and to promote support for the IEEE 1149 family of specifications within the industry. Among their accomplishments was the first product in Tektronix' Integra series of debugging and testing tools—the VX4491 Serial Test Module, a boundary-scan controller for the VXIbus. Products in the Integra series combine Tek's hardware with software from the other two firms—in this case, part of TI's Asset suite and the Virtual Interconnect Test subset of Teradyne's Victory testability package.

VXI PLUGS AND PLAYS. Just as the three Cs of cooperation, consortia, and compatibility play a large role in design for testability, so too are they a major consideration in more general-purpose areas of test and measurement. For example, at AutoTestCon this past September, five important makers of VXI-based instrumentation—GenRad, National Instruments, Racal, Tektronix, and Wavetek—announced the formation of the VXIplug&play Systems Alliance, in their words, "an organization dedicated to increasing ease of use for multivendor VXI systems users."

The VXIplug&play Systems Alliance is intended to complement the work of the VXIbus Consortium, which, since its founding in 1987, has concerned itself with the specification of a broad range of baseline technologies capable of remaining useful for many decades. To meet that goal, it has purposely avoided such issues as fixturing, protocols for shared-memory communication, I/O drivers, instrument drivers, and programming languages.

The new alliance will have no hesitation in dealing with those matters, and will even go so far as to endorse certain products, recognizing that they are already *de facto* standards.

SHARING THE WEALTH. Tight budgets in the test and measurement business have given birth to some interesting phenomena. One of them, borrowed from the computer world, is the concept of the shared resource—what one might call a measurement server—an expensive measuring instrument shared by many engineers over a local-area network.

The first example of this class of instrument was Tektronix Inc.'s Enterprise DAS, an X Windows–compatible version of the Beaverton, Ore., company's well-known digital analysis system, which can easily cost more than US $30 000. With the Enterprise DAS, several engineers working on the same project can investigate the behavior of the unit under test from their individual workstations without leaving their offices. Moreover, they can integrate data from other X Windows software, giving them perspectives on their work that were previously lacking. (It is understood, of course, that they would access the DAS one at a time, just as documents shared over a network can be edited by only one person at a time. It would create havoc if two or more people attempted to control the instrument simultaneously.)

SMALL IS GOOD, TOO. Interestingly, at the same time that they are moving ahead at the top end of the market with products like the Enterprise DAS, big instrument makers are also rediscovering the value of less expensive gear. Hewlett-Packard, for example, is putting a good deal of emphasis on its Personal Measurements Operation, which it created about a year and a half ago to provide instruments for users who need less than state-of-the-art performance.

As Mike Gasparian, general manager of the operation, explained it, in many cases, the cost of an instrument can be reduced dramatically if it is carefully conceived to offer what he calls Just Enough Features—that is, if it omits those capabilities and specifications that are needed or wanted by only a small number of users, but that contribute disproportionately to an instrument's cost. As an example he cited programmable front and rear input terminals. "Giving the user the ability to program which terminals are active adds a lot to an instrument's cost," he said, "but our research indicated that only 2 percent of the users cared about it."

"Of course," Gasparian pointed out, "there is a lot more to making a successful low-cost instrument than just leaving things out." In particular, the instruments made by his operation are also distinguished by extensive use of parts and technologies developed for other products. They are also thoughtfully designed to be easy to manufacture, test, and calibrate. And they are sold through such low-cost channels as direct mail, catalogs, and distributors.

Interestingly, manufacturers seem to put more thought into the user interfaces of their low-cost offerings than they do for their top-end products. For example, one of the more frequent complaints about digital scopes is that they are not as responsive as analog units—that is, traces on their screens lag noticeably behind user input when interactive adjustments are made. The trouble is that the system microprocessor has so many things to do that it gets bogged down during interactive adjustments—just when it needs to be at its fastest.

Bearing those complaints in mind, the designers of H-P's 54600 series of low-cost digital scopes separated the acquisition and display functions of their scopes and placed them under the control of separate processors. The result: a display rate of a million points per second, 50–100 times faster than other digital scopes, and sufficient to give users the responsiveness of a good analog instrument.

H-P is not alone in its recent emphasis on relatively inexpensive instruments with outstanding user interfaces. Just this month, in fact, Tektronix is bringing out a hand-held

instrument that gives electrical service technicians the ability to study a signal's shape as well as measure its magnitude [EEs' Tools & Toys, p. 91]. Called the TekMeter, the combined digital multimeter and 5-MHz oscilloscope, which costs about $1000, is just the first in a planned family of smart portables, called TekTools, aimed at the burgeoning field-service market.

The TekTools family has come into existence in large part because of the spread of electronic technology into just about every segment of industry, from manufacturing process control to building maintenance. The burgeoning popularity of such new products as cellular telephones, the replacement of variable-speed dc motors with ac drives, and the increasing problem of "dirty" ac power lines are just a few of the factors making it necessary for craftspeople and technicians to make rather complex evaluations of electronic signals and systems. The "dirty" power problem—that is, the contamination of ac power lines by spikes, harmonics, and other anomalies—is of particular importance as sensitive microprocessor-based controls replace electromechanical relays in many applications.

AUTOMOTIVE TEST. Although it is not a new area, some experts feel that automotive test presents the most exciting new growth opportunity currently available to the test and measurement industry. What's driving it is the rapidly growing electronic content of modern automobiles, which will represent some 25 percent of the value of a new car by the year 2005, according to James DeStefano, program manager for Hewlett-Packard's automotive initiative.

Where today an average automobile contains some $1200 worth of electronics—in radios, electronic engine controls, digital clocks, and, in some cars, air bags and antilock brakes—that figure will rise to something on the order of $5000 per vehicle as some of today's cutting-edge features become standard and new features are implemented. To name just a few, many turn-of-the-century cars will sport active suspensions; four-wheel steering; automatic personalized setting of seats, mirrors, steering wheels, radios, and cellular phones; collision-warning systems; active acoustical noise cancellation; navigational systems; automatic toll collection; and enhanced controls for engines, transmissions, suspensions, brakes, and air bags. Beyond that, things may get really exotic: active collision avoidance, four-wheel steer-by-wire systems, highway condition warnings, dynamic routing, and a host of personal peripherals that can be gathered under the rubric of the mobile office [see figure, below].

To automobile manufacturers, these prospects are both a dream and a nightmare. The dream is selling all that expensive electronics at a handsome markup. The nightmare is ensuring that it works. How do companies whose main expertise is cutting metal suddenly become world-class electronics testers? By teaming up with test experts.

This is hardly a new idea; efforts by Jaguar Cars Ltd., Coventry, UK, to deal with the increasing electronics content of its vehicles go back at least 10 years, to when it asked a small British company (now GenRad Corp.'s Automotive Test Products Division, in Manchester) to develop a tester for its sports cars. The resulting product, launched in 1986, was a service-bay diagnostic cart that guided auto mechanics through complex diagnostic procedures. Its success caught the eye of Ford of Europe Inc., Brentwood, UK, which had GenRad develop a portable diagnostic unit for its cars.

The hand-held diagnostic unit has a liquid-crystal display and touch-sensitive screen. Since it cannot hold all the test information for every vehicle it may be called upon to test, it downloads what it needs from a compact-disc (CD) ROM drive in its companion base station.

Because automotive repair requires expertise in both test technique and information retrieval, it is a particularly suitable field for Hewlett-Packard, with its computer and instrumentation operations. And indeed H-P is a major player in the field, having developed service-bay diagnostic systems for such well-known auto makers as Ford of North America, Fiat, Rover Cars, and Caterpillar. These systems, it should be emphasized, are not pie-in-the-sky dreams. In North America alone, they have been delivered to some 4000 of Ford's 5000-odd dealerships. In addition, H-P has provided 1200 systems for Fiat in Italy, and has made 2000 for Rover in the UK.

One of the keys to successful automotive diagnostics, according to Bill Duncan, managing director of GenRad's Automotive Test Products Division, is flexibility for the mechanic. That is, if there is a fault in a car's central locking system, and one of the doors has a large dent in it, the mechanic should not be forced to follow a rigid routine that checks all four doors in sequence, looking for the trouble spot.

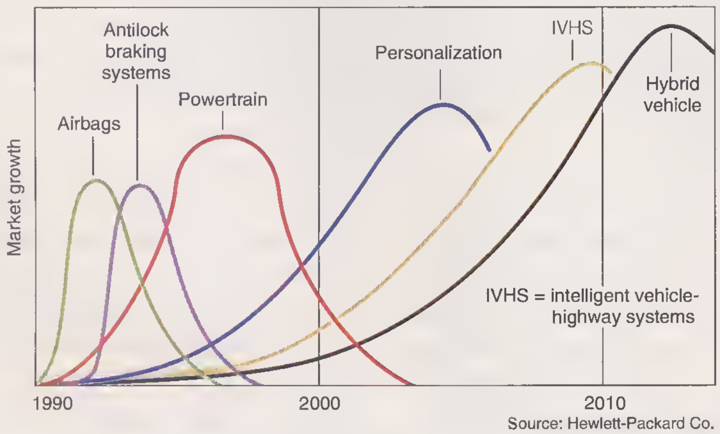
In the future, Duncan said, systems will be even more flexible. They will have the ability to generate alternative diagnostic sequences when circumstances make it impossible to carry out the primary sequence. For example, if a mechanic is working alone, he or she will not be able to press the brake pedal while working under the hood. So the test system must find another way to achieve the desired result. Similarly, Duncan maintains, "just because a technician has broken one of his probes does not mean an end to diagnostics, simply that the computer must find a different sequence to achieve similar ends."

AUTOMATIC CALIBRATION. In the past, calibration was mostly a compliance-driven business; it was required by contract, most often military. Today, a new driver has come on the scene: ISO 9000, the Geneva-based International Organization for Standardization's framework for structuring a quality management system. Stated very briefly, what ISO 9000 says is, write down what you do, do what you have written down, and have a process in place to control things; in other words, develop standardized procedures for everything you do, and then follow those procedures.

Therein lies its relevance to automatic calibration. For, as Don Dalton, marketing manager for the Calibration Products Group at the Fluke Corp., Everett, Wash., put it, "If a documented procedure says that a voltage is to be measured to within a millivolt, the question naturally arises, 'how do you know that you are doing what you said you would do?' "

Calibration, especially of very accurate instruments, has always had a human element, and people are not always consistent. They sometimes forget to dial in proper correction factors; they occasionally use the wrong kind of leads; and they frequently differ in their judgment about when a pointer is exactly at zero.

Computers can help eliminate those inconsistencies. In the very best instance—what Dalton calls closed-case calibration—



If Hewlett-Packard Co.'s analysis is correct, air bags and anti-lock braking systems will turn out to be small potatoes compared with coming developments in powertrains and personalization. Even more hopeful is the promise of IVHS and hybrids for the longer term.

FAUBERT: Mainstream logic designers need to master new hardware and software design skills

Advanced microprocessor technology has made an indelible mark on leading-edge electronic products. The Intel 80486, for example, pushed computer system clock rates up to 66 MHz, pumped the bulk of system functionality into software, and boosted pin counts up to the hundreds. In response, market leaders such as Intel, Compaq, Apple, Sun Microsystems, and IBM have made fundamental shifts in the way they develop products that are inherently faster, more heavily dependent on software functionality, and physically denser.

VIEWPOINT

Now chip manufacturers have designed special versions of their microprocessors—with lower prices and power-saving modes, for example—for mainstream applications. To use these chips, most system designers will have to assimilate the techniques, procedures, and equipment defined by the leading-edge companies for system design and verification, along with a formal method for software development.

The challenges of using advanced microprocessors result from three general characteristics of today's microprocessor-based systems: faster signals, larger software content, and denser physical packaging.

The faster signals require that designers of microprocessor-based systems master some unfamiliar technology. With clock rates often exceeding 33 MHz, pulse edges may measure less than a nanosecond—roughly the same magnitude as the propagation delay along the interconnect in an electronic assembly. Consequently, digital signal paths behave more like transmission lines than lumped-parameter media. To understand and accommodate the resulting analog effects in the signals, systems designers will have to familiarize themselves with transmission-line theory.

The problem is compounded by the extremely fine pin spacings and dense interconnect requirements of modern IC packaging, which forces the signal lines on printed-circuit boards to be very close to each other. The combination of close proximity and high speed aggravates crosstalk effects. In addition, fast pulse edges and fast, simultaneous switching of many signals along 32-bit data paths can induce a voltage drop in ground connections. This ground bounce reduces system noise margins.

To control these effects, systems designers will need to model the physical structure of their IC packaging and assembly interconnect. By applying expected signal waveforms to the physical models, they can then predict high-speed signal effects—and design around them.

Furthermore, the designers' instrumentation must be sophisticated enough to catch any timing problems, however infrequent, when high-speed effects persist in prototype systems.

The larger software content of today's computer systems is made possible largely by the high clock rates and sophisticated designs of advanced microprocessors that are capable of executing many millions of instructions per second. This bandwidth can perform most of the functions in a mainstream electronic product. In fact, it often allows designers to create products with many more features than previously possible.

'The challenges of using advanced microprocessors result from three general characteristics of today's microprocessor-based systems: faster signals, larger software content, and denser physical packaging'

As a result, systems designers who incorporate a new microprocessor into a product can expect to spend much more time on software development than they did with previous generations of products. Instead of creating line after line of firmware, they must adopt a top-down system design approach to software development, one that largely replaces firmware engineering with a formal software department dedicated to developing structured code.

Once the software is developed, systems engineers must find an efficient way to debug their code. They can use the sophisticated debug and system integration tools already in use at leading electronics companies. These tools can work in a networked environment to support and facilitate a team approach to software engineering.

The tight pin spacings of the packages in which advanced devices are housed are a particular source of frustration. Some surface-mounted packages have extremely fine pin pitches—0.5 mm and even smaller—which are difficult or impossible to probe with conventional means.

To accommodate the higher pin count of these devices, electronic assemblies—both printed-circuit boards and multichip modules—use more signal layers and finer traces, both of which further complicate probing.

On the other hand, with the sophistication of microprocessor-based products, the need for access during prototype debug and manufacturing test is only increasing. Systems designers must therefore create ways to ensure that their designs can be tested and verified. For starters, they should consider innovative mechanical access techniques, such as flexible probe adapters.

More important, systems designers need to use design for testability (DFT) methods right from the beginning of the design cycle. The most widely practiced and supported DFT method, boundary scan, has already been implemented in some microprocessors and is supported by instrumentation and automatic test systems. Besides this proven approach, other electrical test methods such as built-in self-test promise to improve testability in the next few years.

Working with top test and measurement manufacturers, leading-edge systems designers have already developed and adopted solutions for controlling the complications introduced by advanced microprocessors. Now these solutions are beginning to trickle down to the general community of systems designers. By working closely with manufacturers of test and measuring equipment, mainstream systems designers can learn about those new tools and use them to put advanced microprocessors to work.

Richard (Richie) Faubert has more than 25 years' experience in the test and measurement industry and is currently the general manager of the Instruments Business Unit at Tektronix Inc., Beaverton, Ore., where he has P&L responsibility for six product lines. Previously, he worked for GenRad (formerly General Radio Co.) as a design engineer and later held continually advancing positions in various areas. He spent his last five years with GenRad as vice president of new product development. He is also the president and a director of Colorado Data Systems and is on the board of directors of Radisys Corp.

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both the instrument being calibrated and the calibrator are controlled by a computer, most often via an IEEE 488 bus. The case remains on the instrument, ensuring that the electromagnetic and thermal environments will be the same as in normal use, and human judgment is reduced as a variable.

For instruments that cannot be completely controlled by a computer, various degrees of automation are possible, from computer-prompted calibration, in which everything is done manually, to computer-aided calibration, in which the computer maintains instrument histories, prompts the operator, calculates errors, and may or may not control the calibrator and instrument settings. With computer-aided calibration, the operator may still take the readings and input data to the computer.

Whatever the degree of automation, it improves the consistency of calibrations and documentation, and can therefore help companies with their ISO 9000 certifications. Since there are only about 2000 certified companies in the United States right now, and experts estimate that between 250 000 and 300 000 companies will need certification by the year 2000, automatic calibration is poised to become one of the market's brighter spots in the years ahead. ◆

Power and energy

Was the 1992 passage of the sweeping U.S. Energy Policy Act a fluke—a rare instance of policy consensus amid a status quo marked by drift and disorganization on energy issues?

Disturbingly, last year's signs tend to confirm this thesis. In July, the U.S. Senate unceremoniously discarded the Clinton administration's widely criticized BTU tax, the culmination of intensive study and a succession of energy-tax proposals. Moreover, the Senate acted in the wake of a presidential election in which energy issues were "clearly *not* on the national agenda," in the words of Charles Ebinger, executive vice president of the International Resources Group, a consulting organization in Washington, D.C. Ebinger had advised the Clinton campaign on energy issues.

"We are in a period of deep need for self-correction with the Clinton energy program," Ebinger concluded after surveying the young Administration's false starts on the energy front in a speech last summer before the Carnegie Council on Ethics and International Affairs, in New York City.

A similar spirit of ineffectuality gripped Europe. Years of struggle to abolish national monopolies of electricity sales and transmission, as well as to open up Europe's transnational power grids, have pretty much come to nothing. Disgusted by the lack of progress, the competition minister of the European Union (formerly called the European Community), Karel van Miert, sought last May to haul six countries before the European Court of Justice to force an end to their recalcitrant national monopolies.

In Asia, meanwhile, inadequate supplies of electricity seemed to be the chief culprit holding back a number of buoyant and burgeoning economies. Throughout the region, there was no discernible letup in the scramble for more megawatts; giant projects were announced and construction contracts awarded—many to Western companies—for work in Indonesia, Malaysia, Hong Kong, Vietnam, and Japan.

IN WITH THE NEW. Problems of a very different sort confront the more mature, diverse, and freewheeling U.S. utility industry, which is often closely watched in matters pertaining to energy policy and operations practices.

Glenn Zorpette Senior Associate Editor

Formulating effective regulations in these areas is the responsibility of the U.S. Federal Energy Regulatory Commission (FERC) and, to a lesser extent, of the Department of Energy (DOE); thus the appointment of top officials for both agencies was among the Clinton administration's most significant activities in energy policy.

Among industry insiders, attention focused on the FERC, where a host of critical issues await resolution or implementation. Extraordinary circumstances gave the new President an opportunity to name four of the FERC's five commissioners. Although opinions vary on his appointments, the commission has earned early praise in some quarters for quickly affirming its commitment to fostering competition in U.S. electricity markets and for patching up relations with the National Association of Regulatory Utility Commissioners, an organization of state regulators with whom it must cooperate in regulating interstate utility holding companies, wholesale purchases of electricity, and so forth.

"The four new commissioners of the FERC and chair [Elizabeth] Moler are actively engaged in these areas, and we are delighted," said David K. Owens, senior vice president for finance, regulation, and power supply policy at the Edison Electric Institute (EEI), the trade organization representing U.S. investor-owned utilities. In the past, he noted, "the criticism was that the staff was fully engaged on these issues and the commissioners were not."

Of particular interest is how the FERC will implement the new powers invested in it by the Energy Policy Act of 1992. These encourage competition in two significant ways. The first is the streamlining and liberalizing of the rules on the formation of exempt wholesale generators of electricity, producers who sell electricity to utilities but are not subject to the regulations governing them. Previous U.S. legislation created and sustained these exempt wholesale generators, but the Energy Policy Act loosened the rules to permit more kinds of organizations to qualify under this category. (This far-reaching legislation was described in more detail in last year's "Power and energy" roundup.)

HIGHLIGHTS

- **Policy ineffectuality rules**
- **New FERC commissioners get involved**
- **The Clean Air Act encounters a rocky start**
- **Asian shortfalls reach crisis levels**

These looser rules were adopted March 20, and within seven months some 80 applicants had filed to be exempt wholesale generators. At press time, 50 applications had been approved, 11 were denied or withdrawn, and the rest had not been decided.

Since the formation of more of these exempt wholesale generators does little for competition without provisions for getting their electricity wherever it may be needed, the act included strong clauses permitting the FERC to order utilities to transmit power for other organizations—exempt wholesale generators, municipal utilities, and independent power producers, for example—at "just and reasonable" rates determined by the FERC. This was the Energy Policy Act's second—and to many observers more important—competitive measure.

"Transmission access is the big issue this year," said Alan Richardson, assistant executive director of the American Public Power Association, a Washington, D.C.-based trade organization representing municipal and other publicly owned utilities. "There is no Clinton energy plan as such," he continued. "But it would certainly appear that we have new commissioners sensitive to the procompetitive aspects of the national Energy Policy Act." Although the FERC is still sorting out many details of how to implement them, the beginnings of an industry-wide transformation are already evident, in Richardson's view.

"What's exciting are the changes that are going to be occurring in this industry as a result of transmission access," he said. "What we are going to see is a much more competitive bulk-power market. There will be more generators of bulk power and more opportunities for utilities to work the market. Several investor-owned utilities are viewing the municipal utilities as market opportunities, since the municipals are no longer tied to the investor-owned utilities around them. There's a different attitude in some areas. We are already seeing rate reductions in bulk-power contracts."

Indeed, the extent to which private and public utilities have sought to use the legislation for mutual advantage rather than confrontation was somewhat unexpected. Nonetheless, disputes over the use of expensive and limited transmission resources are inevitable. In an attempt to formulate more detailed policy for coping with them, the FERC issued a notice of inquiry inviting comment on how bulk-power transmission sys-

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tems should be used, how their use should be priced, and so on. Many investor-owned utilities, in particular, have chafed under some of the FERC's practices in this area.

Suppose, for example, that one utility is supplying electricity to another in a short-term economy, or "opportunity," transaction, and a third party wants to use the utility's transmission system. The FERC permits the utility to be compensated either for the revenue lost because of the discontinued short-term transaction or for the embedded costs of the deal with the third party—whichever is higher. Embedded costs are an estimate of the deal's total costs, including fixed and operating costs, depreciation, and even such minutiae as the cost of sending bills and paying accountants' salaries.

The Edison Electric Institute's position is that the utility should be compensated for the sum of the two quantities, a better reflection of its true costs, according to Owens. A related issue concerns third-party transactions in which the flow of electricity, not now controllable to any meaningful extent, precludes an opportunity transaction. At present, utilities cannot demand compensation for the lost opportunity, a prohibition the institute is seeking to have lifted.

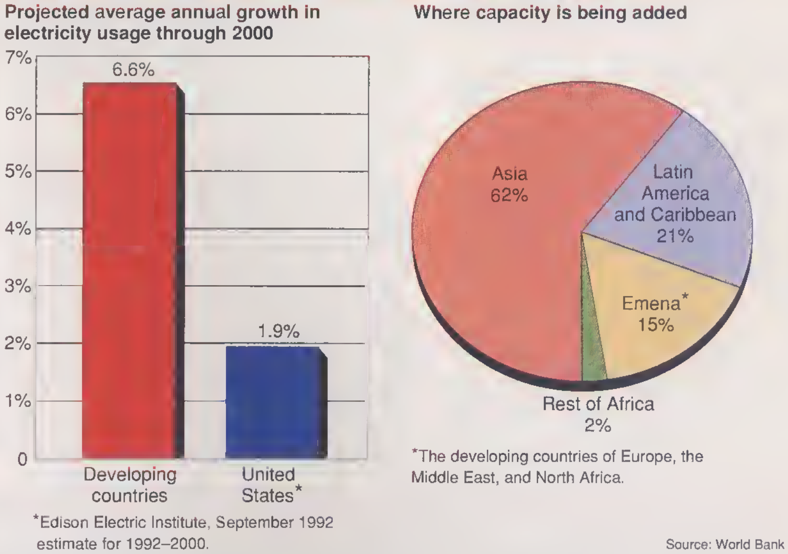
Technology will eventually help solve such problems, though a decade may pass before it is in widespread use. The first of several long-awaited Flexible AC Transmission Systems (Facts) was formally unveiled by the Electric Power Research Institute, Palo Alto, Calif., last September [see Narain Hingorani's "Viewpoint," next page]. Facts and its descendants will eventually give utility engineers more control over load flows.

Such prickly transmission issues have become downright thorny in Europe, where they are seriously complicated by the international dimension. Although the European Union has been trying to foster competition in its electricity markets for almost as long as the United States has, progress has been limited, to say the least. Last spring, van Miert, the competition minister, accused Spain, France, Italy, Ireland, and the Netherlands of breaking Union rules by maintaining electricity transmission monopolies. His aggressive stance surprised utility officials and other Union bureaucrats, who had expected the Belgian socialist to be less zealous in pushing competition than his predecessor, Sir Leon Brittan.

Department of Energy R&D budgets

	Fiscal 1993	Fiscal 1994 request
Nuclear energy	345.4	182.2
Solar renewable energy	257.3	327.1
Energy efficiency	584.5	788.8
Clean coal technology	0.0	250.0
Natural gas	90.5	100.9
Petroleum	62.4	80.9

Power-equipment markets in the developing world



With electrical demand growing at a rate more than three times that in the United States, the importance of the developing world as a market for heavy-electrical equipment is surging. Within the developing world, Asia accounts for nearly two-thirds of capacity additions.

Even so, there was absolutely no talk of a U.S.-style solution, in which, for example, the Union's energy directorate could order a national utility to wheel electricity and set fees for the service. Instead, the Union was said last summer to be considering a policy that would require a utility to explain itself if it refused to transmit power for two other parties.

WHAT POLICY? In the United States, the much larger question of a sensible, long-term policy remains elusive, some believe, despite the passage of the Energy Policy Act and progress on transmission access. According to Ebinger, the country is "pursuing a strategy, for the most part, in which the plants being built are the ones that can be built at least cost. Life-cycle costs are ignored. That means that natural gas, combined-cycle plants are now the plants of choice."

Ebinger's fear "is that I don't believe that natural gas is going to remain cheap," he explained in an interview. "What has stood this country very well for decades is a diversified energy mix. We should continue that policy while exploring new technologies as well: solar, clean coal, second-generation nuclear, hydrogen."

With one notable exception—nuclear power—the Clinton administration's 1994 budget does support a wide range of advanced generation technologies [see table, left]. Funding in nuclear research and development will, however, drop from US $345.4 million last year to $182.2 million in 1994, reflecting the Administration's intention to curtail work on future generations of reactors.

Other winners in the Clinton budget include renewable energy and conservation programs, particularly those involving the commercialization of research, the processing of industrial wastes and materials, electric and hybrid vehicles, advanced ceramics and other materials, and modeling of the operation and interaction of the electrical systems of buildings and the environment. From 1994 to 1998 the proposed DOE budget for renewable energy and conservation will come to about $1.9 billion.

Among utilities, most conservation activities fall within a category called demand-side management, a catchall term for programs that promote the use of more efficient lights, appliances, and equipment among both commercial and residential customers. Most of these programs are actively encouraged by state government and regulatory agencies, setting up a subtle tension with the FERC's agenda of giving large users of electricity an attractive array of supply options, such as cogeneration, buying power from an exempt wholesale generator, or actually becoming an exempt wholesale generator.

"It is difficult to provide for social ratemaking in an environment where there is increasing competition," noted the EEI's Owens. "How that will shake out, I have no idea," he added. "But I would argue that utilities have to have options," such as making deals for bulk power, pushing demand-side management, or some combination of these or other strategies.

NO FREE LUNCH. Utilities planning their energy future need accurate projections of the costs and benefits of all their options. Research by two economists at the Massachusetts Institute of Technology, in Cambridge, has raised eyebrows by suggesting that utilities often systematically understate the costs of energy conservation and overstate the savings.

In an article in the July issue of *The Electricity Journal*, Paul Joskow and Donald Marron reported that a study of 10 demand-side management programs revealed average costs of 3.4 cents per kWh saved—more than five times the 0.6 cents cited by the Rocky Mountain Institute, Boulder, Colo., and substantially above other industry estimates

as well. The authors did not question the soundness of demand-side management in itself but concluded: "while we think that there is more than a free snack out there that utilities can help to capture, the free banquet with caviar and champagne that the public is often promised is not likely to be achievable with current practices."

Unfortunately, this scenario seemed to be characteristic of last year's trend: good ideas and intentions about energy undermined by confusion and inadequate planning. Take the Clean Air Act amendments, which are more than three years old, though Environmental Protection Agency (EPA) officials still have not decided how to implement them. Last summer, after U.S. utilities had drawn up complex plans to comply with the amendments, the EPA changed a number of provisions, rendering some plans invalid.

"This has created some confusion in the marketplace," said Alan S. Taylor, a senior associate in the Boulder, Colo., office of RCG/Hagler, Bailly Inc. "Some utilities run the risk that their compliance plans might not be accepted."

The changes mainly involved the reduced-utilization and substitution-unit rules, which deal with moving up the compliance date of generating plants that otherwise would not be affected until the year 2000. Under the agency's original plan, a utility that voluntarily advanced the compliance date for such units to 1995 (rather than 2000) would reap various benefits; the changes, however, scaled them back.

This was said to have been partly responsible for the enervation of the EPA's novel emissions-credit trading scheme after a much ballyhooed start. The basic idea was to curtail pollution by literally requiring utilities to pay for the right to pollute beyond a certain level. Last March 29 the EPA kicked off the program by holding a Chicago auction in which "allowances" permitting a utility to emit 1 ton of sulfur dioxide were sold at prices ranging from $122 to $450 apiece. For comparison, scrubbing a ton of that pollutant from a smokestack is said to cost as much as $500.

Shortly after the auction, an electronic Allowance Tracking System was supposed to automate the whole process, permitting the allowances to be bought and sold much like any other commodity. The EPA, however, failed to get the system working. Then the rule changes produced confusion, which took

HINGORANI: The Energy Policy Act compels utilities to unbundle generation, transmission, and distribution

VIEWPOINT

During 1993, the electric power industry in the United States started a period of unprecedented change as a result of the Energy Policy Act of 1992. Among other provisions, this act mandates wholesale access to utility transmission systems by nonutility—and largely unregulated—generators. Given the different regulatory oversight and competitive forces for the various parts of the utility business, the act is in effect causing utilities to unbundle their traditional services of generating, transmitting, and distributing power.

Under varying circumstances, unbundling is also taking place, or has taken place, in many countries around the world, where the key motivation is to privatize the government-owned utilities and introduce competition on the generation side. Many developing countries are also motivated by the need to attract capital to finance, build, and operate electric energy facilities.

Generally, vertically integrated utilities are beginning to move toward a more loosely connected, three-part business structure. The generation side of the business is emphasizing least-cost production and wholesale marketing of electric power as a commodity. The transmission side is emphasizing integration and wheeling under set, or yet-to-be-defined, rules, and the distribution side is emphasizing value-added services to meet specific customer needs.

As utility services are being unbundled, however, the vast interconnected power systems must continue to operate as a tightly integrated unit to ensure an economic and reliable power supply. Indeed, the electric power system is probably the most complex "machine" ever invented, with individual parts—such as generators separated by thousands of kilometers—moving together with millisecond synchronicity. The highly interconnected transmission grids that span control areas and state and national boundaries are essentially the glue holding the generators and loads together. From a technical point of view, the greatest challenge posed by open access and increasing competition is to ensure that this "glue" continues to hold, and that the economies of integration enhance interconnected systems without sacrificing their security, even as utilities themselves change fundamentally.

In the United States, about 40 percent of the electricity generated is sold by the producing utilities through wholesale transactions to other utilities. Unbundling transmission services will probably increase the number of bulk sales and alter the power-flow requirements considerably. Also, more players—including unregulated, independent power producers, some large and some small, and many without high-speed controls—will be using the transmission network to make increasingly complex transactions. Put bluntly, the transmission systems are being required to perform services for which they were *not* originally intended.

'From a technical point of view, the greatest challenge posed by open access is to [enhance economy] without sacrificing . . . security'

To maximize power transfer, the Electric Power Research Institute (EPRI) has pioneered a technologically sophisticated, power electronics-based Flexible AC Transmission System (Facts). Through selective use of thyristor-based controllers, Facts offers utilities a unique, threefold opportunity to meet the challenge of transmission access. First, its technology enables them to increase or decrease power flow on specific lines. Second, the incomparable speed of thyristor switches allows almost instantaneous control of transient disturbances. Third, Facts controllers allow transmission lines to be loaded closer to their inherent thermal limits, thus enhancing the available capacity of transmission systems. Small wonder, therefore, that interest in Facts technology is already running high.

Improvements in power quality are also continuing, particularly in the industrial and commercial sectors. Increasing automation has brought not only increased productivity but also greater vulnerability to what were once relatively innocuous disturbances in power systems. On today's automated lines, a loss of power for one cycle can interrupt production or lead to defective products.

Also vulnerable to a variety of other power disturbances are the integrated circuits that are the heart of manufacturing system controls. These chips can unfortunately be damaged by sags, surges, harmonic distortion, and high-frequency electronic noise.

In response to the problem, EPRI has pioneered a power electronics-based system called Custom Power, which utilities may use to provide customized, higher-quality power to customers with sensitive loads. Initial users of the service are expected to be large industrial facilities and commercial development parks.

In generation, too, there have been big changes. The low cost of gas in many developed countries coupled with the increased efficiency of combined-cycle gas turbines, rapid delivery of small units (up to about 200 MW), and a favorable regulatory environment have shifted new generation from large central power plants to small or gas-fired ones installed closer to the load centers. Although they are now supplanting large, central power plants, it is unclear if in the long run customers will end up paying less or more for their electric energy.

In the developing countries, on the other hand, coal and hydroelectric units predominate among the facilities under construction. With the demand for electric energy surging

its toll on the market in allowances. "Utilities that thought they had credits to sell are now finding they may need to buy them," explained Taylor.

RUNAWAY GROWTH. Such problems are best viewed in perspective, since many an Asian country would gladly substitute them for its own. Almost everywhere in Asia, the story is the same: electrical demand, already well above capacity in most places, is growing at a pace that outstrips any realistic plans to keep pace with it.

In one of the most troubled countries, the Philippines, President Fidel Ramos signed a bill last April giving him special powers to address a supply situation so bad that daily outages of up to 8 hours had become normal. A power failure in Malaysia blacked out most of the country for as many as 24 hours last September. More than half of Indonesia's 185 million people do not have electricity at all. In Vietnam, a drought caused outages that lasted four days a week for several weeks in Ho Chi Minh City (formerly Saigon).

As might be expected, these and other Asian countries are adding capacity as quickly as their resources allow. The world's largest suppliers of power generation equipment, General Electric Co., Fairfield, Conn., and ABB Asea Brown Boveri & Cie. AG, Heidelberg, Germany, believe that Asian orders will account for roughly a third of their equipment sales over the coming decade, up (in the case of ABB) from about a fifth today. According to the World Bank, additions to Asia's electric capacity already account for 62 percent of the increase throughout the developing world [see chart on opening spread].

Early in 1993, the Indonesian government granted an investment license to Mission Energy Co., Irvine, Calif., which is leading a consortium of U.S., Japanese, and Indonesian companies in a planned $2 billion project to build two 600-MW coal-fired plants.

In the Philippines, a bitter, five-year legal fight over an eight-year-old, $2.3-billion, 620-MW nuclear plant on the Bataan peninsula appeared at an end. In October, President Ramos announced that the Government was close to an out-of-court settlement with Westinghouse that would oblige the Philippines to drop all litigation against the company and to cease eschewing its products, in exchange for two 100-MW turbines valued at about $50 million.

AMBITIOUS RESTRUCTURING. If the deal was good news for Pittsburgh-based Westinghouse, it came in a year when the once colossal equipment maker needed all it could get. Troubled by bad loans from a calamitous venture into financial services in the 1980s, the company is in the midst of an ambitious restructuring. Last year, CEO Paul E. Lego departed with a vast severance package; Michael H. Jordan was appointed to succeed him; and the company's electrical distribution and control equipment business was sold, for $1.1 billion plus certain liabilities, to Eaton Corp., Cleveland, Ohio. The sale was the first of four that are planned to help Westinghouse escape its crushing debts.

On the brighter side, the company's recent turbine partnerships—one with Mitsubishi Heavy Industries and FiatAvio, the other with Rolls Royce—seem to be doing well. In August, the Tennessee Valley Authority (TVA), Knoxville, gave the Westinghouse-Rolls Royce alliance a $39 million contract to supply four low-pressure turbines to the TVA's Colbert Power Station, in Alabama. Last year, Westinghouse and Mitsubishi commissioned a 1725-MW combined-cycle plant—Britain's largest—in Teesside, England.

Overall, Westinghouse's power generation business, based in Orlando, Fla., has in five years seen its annual sales rise $1 billion to $1.7 billion. The Westinghouse-Mitsubishi-FiatAvio triumvirate is now the world's second largest producer of combustion turbines, behind General Electric.

Like GE, Westinghouse has managed to keep its nuclear business alive with maintenance, service work, and overseas orders, or the prospect of them. It is increasingly doubtful, however, that this state of affairs can be sustained. In a report last September, the congressional Office of Technology Assessment (OTA) concluded that "long-term prospects for the 107 operating plants that supply more than 20 percent of the electricity [in the United States] are increasingly unclear."

The economics of nuclear power have come to seem less and less appealing against a backdrop of more and more competition in U.S. power markets. In the past four years, the report noted, six plants have been retired long before the expiration of their operating licenses.

One of the afflictions besetting the U.S. nuclear industry is the lack of a repository for high-level nuclear waste. In August, reflecting the urgency of the problem and a general lack of confidence in the DOE's ability to implement its plan to open a permanent repository beneath Nevada's Yucca Mountain in 2010, the industry began seeking an interim repository. Talks were held with several Native American tribes about the possibility of setting up such a repository on their lands in exchange for payments that could be as high as $50 million a year for two decades.

WELCOME TO THE CLUB. On the whole, there were relatively few auspicious nuclear developments anywhere in the world. At press time, North Korea's transformation into a renegade nuclear state seemed almost complete: as a result of the protracted on-again, off-again standoff between it and the Vienna-based International Atomic Energy Agency (IAEA) over a nuclear research facility at Yongbyon, that country was declared in violation of its obligations as a signatory to the Nuclear Nonproliferation Treaty, from which it announced its withdrawal in March. Few doubt that North Korea is attempting to hide a weapons program.

Any doubt that Iran has such a program seems to have been removed by a report last March that the country had secretly obtained beryllium—a critical component of a bomb's neutron trigger—from Kazakhstan. Under agreements reached in 1992, Russia is selling Iran two VVER-type reactors.

In the light of these developments, the dismissal of an aggressive and experienced nuclear-industry inspector was disturbing indeed. David Kay, who led some of the first and most successful inspection missions to Iraq after the Persian Gulf War, was fired from his subsequent post as secretary general of the Uranium Institute, a trade organization in London. His op-ed *Wall Street Journal* pieces critical of the IAEA's handling of its responsibilities were said to have angered IAEA director Hans Blix, who reportedly orchestrated Kay's removal. ◆

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in these countries, the multinational companies have turned their attention to meeting those needs.

In the United States and many other developed countries, it has become popular to glorify very small generators under a concept called distributed generation. Modular generation technologies in particular, such as fuel cells, gas turbines, and photovoltaics, lend themselves to this approach. These units have capacities in the range of a few kilowatts to a few megawatts and can be installed quickly, with relatively small financial risk. However, the possibility of these geographically dispersed generating and storage units being connected to a utility's distribution or subtransmission system has raised issues related to the control, reliability, and safety of these systems.

Much progress has been made in developing specific distributed generation and storage technologies. The first commercial variable-speed wind turbine has been introduced and is expected to expand the wind energy market, with prototype units installed in California and New York. Demonstrations of 2-MW molten-carbonate fuel cells are getting under way, and photovoltaics is being vigorously commercialized as a possible significant contributor to the electric supply.

Today the electric utility industry stands poised for the largest transition in its recent history. Rapid deregulation, which received a strong impetus during 1993, challenges utilities to become not only more competitive but also more innovative. Fortunately, a variety of new technological opportunities are becoming available that will help the industry meet the challenges ahead.

Narain G. Hingorani (F) is vice president of the electrical systems division at the Electric Power Research Institute in Palo Alto, Calif. In 1985, he received the Uno Lamm medal from the IEEE Power Engineering Society (PES) for contributions to high-voltage direct-current technology. He is a member of the PES's executive board.

Transportation

Progress in flywheel battery technology, in smart car and road systems, and in several rail systems were among transportation's high points in 1993. And the collision alarm sounded for many of the nation's waterways.

SPINNING WHEEL. Electromechanical batteries—flywheels—emerged as a strong challenge to electrochemical batteries for electric vehicles (EVs) when American Flywheel Systems (AFS) Inc., Bellevue, Wash., demonstrated a working flywheel model in September [see top figure, opposite].

Chief executive officer Ed Furia called it "the silver bullet they said isn't possible." He credited several advances over the last decade: high-strength carbon-fiber composites at lower prices, magnetic bearings, and very large-scale integration electronics to control power output precisely as flywheel speed varies. Until recently, the potential of flywheels was limited because conventional materials shatter under mechanical stress at the speeds needed to store large quantities of energy.

A prototype flywheel, with at least three times the energy density of lead acid batteries, is to be ready for testing late this coming summer. A set of 20 are to outfit a test car by late 1995. Each will be about 18 cm long and 23 cm in diameter and weigh about 23 kg. Total weight would be 273 kg compared with 396 kg for the Impact's current batteries. Furia said they will be able to propel a GM Impact EV 480 km and to accelerate it from 0 to almost 100 km/h in 8 seconds.

"No serious person now questions the feasibility of building a high-energy-density flywheel battery," Furia said. But, "institutional issues are another matter." He noted that strong interest has come from Asia and Europe—but not from Detroit.

Flywheels should have many advantages over electrochemical batteries. Composites degrade gracefully and use no toxic or hazardous materials. Most batteries last 2–4 years versus a projected 10–20 years for flywheels. Furia envisions consumers recharging during nighttime off-peak hours (8 hours at 110 V or 5 to 15 minutes at 440 V). One utility has suggested that it lease flywheels to offset high initial costs. In an assessment for the U.S. Department of Energy (DOE), Abacus Technology Corp., Chevy Chase, Md., estimated that flywheels will meet or exceed most goals outlined by the U.S. Advanced Battery Consortium.

Dave Dooling Contributing Editor

BATTERY FACTORY ON THE HORIZON. A leading EV battery candidate moved forward when Electrosource Corp., Austin, Texas, and BDM Inc., Falls Church, Va., formed Horizon Battery Technology Inc. and (on Oct. 13) dedicated a converted Austin facility to produce the former's unique Horizon woven lead-acid batteries [see bottom figure, opposite]. The first battery was scheduled to leave the production line in January 1994. HBTI factory manager Jack Keane said that about 125 large battery packs of 40 kWh each—equivalent to 3800 12-V battery modules—should be manufactured each month by the end of 1994. The factory makes extensive use of automation, robotics, artificial intelligence and expert systems, and fiber optics, and should have "a zero-emission pollution signature."

The Big Three automakers—Ford, General Motors, and Chrysler—announced that the U.S. Council for Automotive Research (Uscar) will develop EV technologies to meet strict zero-emissions policies set by California and adopted by other states. The U.S. Environmental Protection Agency said it would support California's zero-emissions standards, effectively eliminating any Federal challenge. In New York State, which has adopted the standards, a Federal judge agreed with a U.S. Automobile Manufacturers Association suit calling the rules "an undue burden."

HIGHLIGHTS

- **Flywheel battery technology advances**
- **Aircraft navigation by satellite to expand**
- **High-speed rail initiative announced**
- **U.S. harbor approaches need remapping**

Peugeot Citroen, Paris, will introduce a network of 50 EV-recharging stations in Tours, where it will be possible to rent and drop off 200 EVs. Networks are planned for Coventry, England, and Karlsruhe, Germany. Hydrogen, which will be tested by Mazda Motor Corp., Hiroshima, Japan, with its HR-X experimental car, remains a competing power source. Florida's Energy Partners, West Palm Beach, announced the development for use in automobiles of a prototype hydrogen fuel cell using a proton-exchange membrane.

Several intelligent vehicle-highway systems (IVHSs) completed field tests, and the IVHS 20-year strategic plan was well received by the Clinton administration.

"They are very, very impressed at what it can do," said James Constantino, director of the IVHS America consortium, Washington, D.C., "and they are looking for national laboratories to take a role in the program." A tactical plan to be released in the spring will recommend detailed near-term program objectives.

Constantino said that Japan and Europe also are forming IVHS consortia; Canada, Australia, and Southeast Asia will follow: "Organizationally, IVHS America is the world leader. But the Japanese have been doing certain kinds of systems for about 20 years. While we were building the interstate highway system, they were working on using technology as much as possible."

In a number of U.S. projects, he said, "progress has been exceptional." TravTek, Orlando, Fla., was "an outstanding success, one of the real winners." The one-year test equipped one hundred 1992 Toronadoes with navigational gear; an on-board system keyed to en route guidance systems provides voice instructions and displays computer maps at the driver's request.

Robert Rupert of the U.S. Federal Highway Administration agreed: "In general, everyone was overwhelmingly pleased with TravTek." The 3000 selected customers who rented cars rated the system 5.5 out of a possible 6.0.

In Los Angeles the California Department of Transportation is expanding its Smart Corridor dynamic route-guidance program, which will involve 100 000 cars within five years. Caltrans tested 25 vehicles in the 1992–93 Pathfinder phase. Smart Corridor is used by more than 325 000 cars a day. Two workstations at the Caltrans Traffic Operations Center fuse data to present information to the drivers on computer displays in the vehicles. Drivers liked the system and were not distracted by the map and voice information, although they found that text was difficult to handle. Caltrans engineer Terry Wong said that Smart Corridor succeeded both as a multiagency and as a joint public and private project.

In northwest Chicago, the Advanced Vehicle Driver and Vehicle Advisory Navigation Concept started testing six vehicles in mid-1993. Up to 5000 commercial and private

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This engineering model shows key elements of American Flywheel Systems' new design. Two carbon-fiber rotors (counter-rotating to cancel torque effects) are encased in a vacuum housing [without the window shown here]. Each rotor has eight permanent magnets encircled by a composite mass that becomes the momentum storage device as it rotates at 200 000 rpm. The rotors have a common shaft with magnetic bearings to provide a virtually frictionless spin and to stabilize the rotor when the car turns. Pickup coils on the housing endplates complete the dynamo when the flywheel powers a car, and drive the rotor to recharge the system.

American Flywheel Systems Inc.

vehicles will be outfitted with in-vehicle navigation and route guidance systems in the US $40 million, five-year program.

Motorola Inc.'s Customer Specified Integrated Circuits Division, Austin, Texas, announced a new line of digital products to control automobile systems. Operations manager Brian Gardner said the System Chip 68HC705V8 has the first single-chip multiplexing system and serial bus capable of eliminating many of the dozens of wires that now run throughout automobiles.

"Multiplexing would take a lot of wiring out," said Gardner, and allow the use of standard three-wire interfaces. System Chip, based on Motorola's 8-bit 68HC05, has 12 kB of electrically programmable ROM, 128 bytes of electrically erasable and programmable ROM, and its own on-board voltage regulator. Versions of the chip are to become available during the coming year.

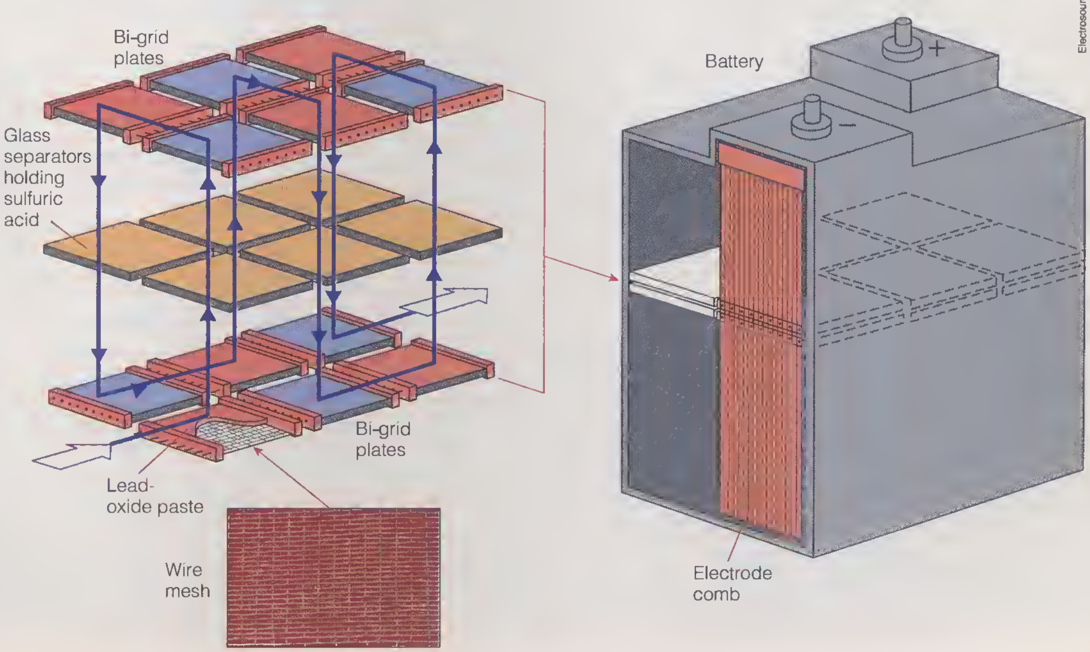
The U.S. Department of Transportation (DOT) announced a five-year, $1.3 billion initiative to expand high-speed rail systems across the nation and to create partnerships with local governments to build high-speed rail corridors. "A strong, technologically advanced rail system to transport passengers is critical to our economic competitiveness," declared new Transportation Secretary Frederico Pena on April 28. Local funds and corporate investment must provide an additional $2 billion.

HIGH-SPEED RAIL PROGRAMS. Under the $982 million High-Speed Rail Assistance Program, Pena will designate high-speed rail corridors in congested areas with the greatest potential. A further $303 million will support technology development—$228 million for a prototype magnetically levitated (maglev) train (now built only in Europe and Asia), and $75 million for developing high-speed, nonelectric locomotives and for safety and signaling systems. Pena suggested that military gas turbine technology be applied to high-speed locomotives. DOT foresees opportunities "to develop urban and suburban stations (often as intermodal terminals) and revitalize surrounding neighborhoods," as well as to divert intercity traffic from highways and to feed airlines while preserving their long-haul capacity.

Amtrak Corp., Washington, D.C., tested Sweden's X2000 tilt-train in the Northeast Corridor. In October, Amtrak also started testing Germany's 260-km/h Intercity Express (ICE) in revenue service on the New York–Washington line. ICE features regenerative braking to return 8 percent power through its three-phase ac drive. Amtrak was to request proposals for 25 train sets by the end of 1993, with service to start in 1997, when the National High-Speed Rail Improvement Project is completed.

California created an Intercity High-Speed Ground Transportation Task Force to plan for at least one high-speed rail line in the state by the end of the century. The Texas High-Speed Rail Authority granted an extra year, to the end of 1993, for Texas Supertrain, Austin, to complete funding; Southwest Airlines opposes support for the project.

In Europe, France opened its third Train à Grand Vitesse (TGV) line and approved a fourth. In its 11 years, the TGV has carried 250 million passengers without mishap. GEC Alsthom, Paris, won a contract to build a 300-km/h TGV line between Seoul and Pusan. Germany started building a 280-km/h ICE line from Hannover to Berlin. And the long-awaited English Channel Tunnel will be opened with all due ceremony by Queen Elizabeth II and French President François Mitterand on May 6.



Electrosource's Horizon battery comprises several layers of woven, co-extruded lead wires built up in grids compressed in a cage and held horizontally, as opposed to the vertical orientation of most batteries. The design eliminates the shedding of active materials and acid stratification between plates. It also improves heat distribution and oxygen recombination. Because the plate design does not depend on fluid circulation, as do conventional batteries, the battery modules can be built to take the shape of various spaces within a vehicle.

In Asia, China plans a 1300-km, 250-km/h link between Beijing and Shanghai. Morrison-Knudsen Corp., Boise, Idaho, won a contract for Taiwan's high-speed rail project.

Maglev Transit Inc., Orlando, Fla., the first U.S. attempt to demonstrate maglev, split with TransRapid, Emsland, Germany, its prime contractor. Maglev Transit is building a 22-km demonstration link between the Orlando Airport and downtown. Spokesman Mike Saegers said the Florida company plans to contract with HSST Development Corp., Tokyo, for a slower train that will still reach the state's 240-km/h requirement. TransRapid's maglev, meanwhile, is a candidate for a rail link proposed between Los Angeles International Airport and the Palmdale, Calif., airport to handle regional and commuter routes. Elsewhere, Hyundai Precision & Industry Co., Seoul, South Korea, was to put its HML-03 maglev in service at 50 km/h on a 560-meter track at the Taejon International Exposition.

SUBWAYS AND LIGHT RAIL. Out West, the 7-km Metro Red Line segment of the Los Angeles subway system started operations; it is to be linked to Green and Blue Lines for a total of 36 km by the year 2001. The L.A. Metropolitan Transportation Authority awarded a contract for 87 light rail cars to German-based Siemens Duewag, Sacramento, and to a team of U.S. aerospace firms that will do much of the work. Last year's award to Sumitomo, Tokyo, was overturned following a "buy American" protest.

Elsewhere, St. Louis, Mo., opened the first 29 km of its Metrolink light rail system. The New York City Transit Authority started its New Technology Test Train Program, which will test various systems using two prototype engines. The best combination will be specified in a planned 1997 procurement that would replace the current fleet of 5487 cars from the 1960s. The high-grade copper that powers and controls New York City's subway

FLAX: Transportation in the Information Age requires intelligence and intelligibility

VIEWPOINT

In modern industrial nations, social, economic, and environmental concerns are increasingly affecting plans and programs to improve local and long-haul transportation. The new 27-km Century Freeway in Los Angeles may be the last—even in southern California, whose form and growth have so long been shaped by the automobile. Air transportation is limited as well: only one new major city airport, in Denver, is scheduled to open in the United States in the near term.

Although subways and other forms of local and urban light rail transportation have recently enjoyed greater interest and popularity—and may be essential to alleviate near-gridlock in some local situations—they could have little impact on highway traffic nationwide.

Similarly, the patterns of long-distance travel in the United States make the prospect of substituting high-speed rail systems for air transportation slim except in densely populated areas along the East and West Coasts, where they can and should be operated. Major efforts should thus be made to utilize the maximum capacity of existing roadways and airways while reducing growth in demand.

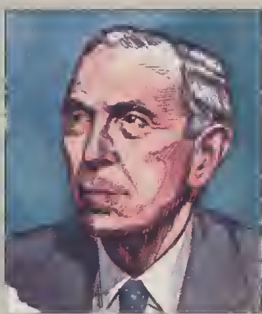
As more and more business is transacted on computer networks and wide-band communications services grow cheaper and more available, prophets of the Information Age argue, workers will operate as effectively from terminals at home as they now do in central offices. Such visionaries also claim that central offices in distant cities will conduct business wherever they please by substituting communications for transportation.

Yet at least for intercity transportation, the increased geographical dispersion of business activities may raise, not lower, the demand for transportation. Technocrats and hackers who find nirvana on computer screens too often overlook the uses and value of person-to-person contact.

Moreover, exchanges of video imagery are not likely to reduce nonbusiness travel for vacations and visits. Information technology developments and the widespread availability and use of communications should nonetheless profoundly influence the development of more efficient transportation systems.

A great deal of public fanfare and substantial private and government effort have been directed toward applying information technology to highways, generally in so-called intelligent vehicle-highway systems (IVHSs).

Yet U.S. highways are notoriously unintelligent. Directional signs are often ambiguous and confusing, and they rarely guide drivers by the most direct or efficient route. Successive signs fail to give consistent information in a logical sequence. Systems providing "real-time" information on less congested alternative routes, and systems that control traffic by feedback rather than through programming or manual adjustment, are limited in number and capability.



'For intercity transportation, the increased geographical dispersion of business activities may raise, not lower, the demand for transportation'

Highway systems are planned, designed, and built mainly by modern counterparts of the architects of the Appian Way. They pay little attention to the role of information technology in the efficient operation of highways. Some 20 years ago, as a member of a U.S. Department of Transportation advisory committee, I proposed that a small fraction of Federal highway funds be set aside for highway "software." This idea went over like a lead balloon. Since then, little progress has been made in systematically analyzing highway information transfer and its effects on the capacity of highways and the efficiency of their utilization. The need to understand and address these questions is central to effective and safe operation of highways, no matter what degree of intelligence may be incorporated within an IVHS.

Information technology specialists have been similarly deficient in appreciating the function of human cognition and its relation to the operation of machines and systems. How many people, after all, venture to program their videocassette recorders or know how to use all the functions of a modern telephone? User intelligibility seems to be low on the industry's list of design criteria. Failure to correct this deficiency will doom any IVHS to failure.

The Global Positioning System (GPS)—with relatively compact, low-cost vehicle receivers providing accurate positional information—can be integrated with highway or airway information technology to improve the efficiency and capacity of our transportation systems.

Although many commercial, industrial, military, and sporting activities use the GPS, the United States still has no comprehensive plan to employ the system in highway or airway information and control systems. Indeed, the Federal Aviation Administration seemed to be the last body in the world air transport community to contemplate using GPS in air traffic control even in over-ocean traffic.

For both highways and airways, systems-oriented engineering teams must study the cognitive aspects of human interaction with transportation systems; evaluate systems architectures, standards, and man-machine interfaces; and consider cognitive human factors along with established systems-engineering criteria and methods.

We must decide which functions will be performed by vehicle systems and which will be provided as a part of the overall transportation infrastructure. Otherwise, we will find ourselves, some years hence, with collections of unintelligible and not very useful hardware.

Alexander H. Flax is a senior fellow of the National Academy of Engineering. His leadership roles in aeronautics and defense span a half century and include chief scientist for the U.S. Air Force and president of the Institute for Defense Analyses.

system has become a pet target for thieves, causing delays and one death. The People's Republic of China will build or extend subways in eight large cities to relieve street congestion.

FLY THE CROWDED SKIES. Looking to the year 2010, the International Civil Aviation Organization (ICAO) proposed in July that aircraft be equipped to use global navigational satellite systems (GNSSs) to facilitate the projected doubling of air traffic early in the 21st century. ICAO planned a task force to evaluate whether its needs can be met by the U.S. Global Positioning System (GPS), Russia's Glonass, or a civilian GNSS. An interim report is due by midyear.

In September 1993, an airliner equipped with GPS receivers demonstrated a fully automated approach along the Potomac River to land at Washington (D.C.) National Airport. The U.S. Federal Aviation Administration (FAA) has planned a transition over a period of 10 years from using GPS as a supplement to using it as sole navigational source.

A potentially widespread application would have aircraft broadcast their identity and GPS-derived position and velocity to help other aircraft and air traffic control facilities in avoiding or preventing collisions and setting routes. MIT Lincoln Laboratory, Boston, and Hughes Aircraft, El Segundo, Calif., advocate using Mode-S radar transponders to broadcast data every second. FAA and the Lincoln Laboratory plan to test the scheme in a traffic alert and collision avoidance system at Boston's Logan International Airport early this year.

The FAA and IBM Corp. shared the blame for delays in the Advanced Automation System (AAS) being developed to update the aging U.S. air traffic control system. Problems with software, human factors, and design changes have put AAS three years behind schedule and $1.5 billion over budget. IBM, awarded a $3.1 billion development contract in 1988, has had difficulty linking the control centers. The first unit is to be delivered to the FAA Technical Center in April 1994. A planned consolidation of 230 en route and terminal facilities into 23 area control facilities was revised to produce 10 area control facilities and 170 upgraded terminals.

The U.S. National Commission to Ensure a Healthy, Competitive Airline Industry examined the financial crisis that has drained the airline industry of $10 billion since 1990. Its 60 recommendations include privatizing and modernizing the FAA. American Airlines and other carriers banned passengers from using electronic devices during takeoff and landing; hand-held games are banned entirely. Nonetheless, no rigorous tests have verified pilots' claims that the devices have caused fluctuations in the functioning of navigational gear.

At the Raleigh–Durham, N.C., airport, the FAA has tested a precision runway monitor (PRM), an electronically scanned radar that allows aircraft to use parallel runways at closer intervals in time. The first operational unit is to start up at the Minneapolis–St. Paul airport by May 1995.

Wind shear was not neglected. The FAA and National Aeronautics and Space Administration (NASA) finished evaluating doppler microwave radar, laser radar, and infrared sensors that could warn pilots up to 40 seconds before they encounter wind shear or downbursts. Most airlines had until the end of last year to finish outfitting their aircraft with equipment that will help pilots react to wind shear but provides no warning. NASA planned a $63 million program to make instrument flight rules (IFR) easier for general aviation. Objectives include halving the costs of IFR systems and the training time to use them, and new protocols for developing avionics.

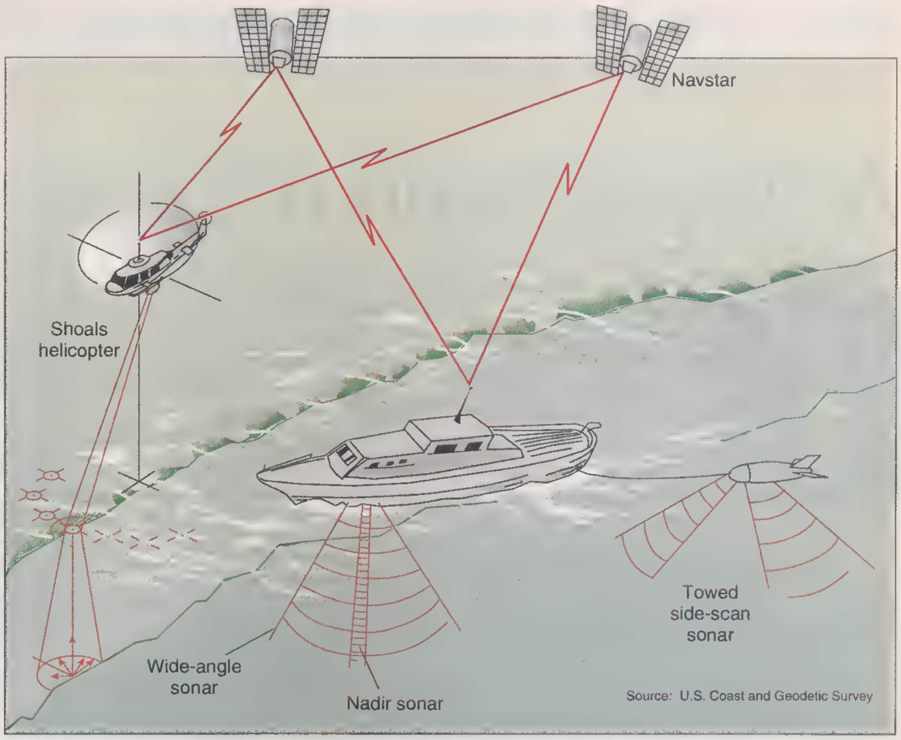
WATERWAYS NEED REMAPPING. The U.S. Coast and Geodetic Survey (C&GS) plans a high-resolution remapping of priority portions of the nation's 152 380-km coastline. Captain Donald L. Suloff said C&GS cannot keep up with the 500 hazards mariners report each year.

One-quarter of U.S. harbors and harbor approaches, and half of U.S. waters less than 30 meters deep, have not been mapped since World War II. "Some 40 000 square miles [100 000 km^2] of water are critical in terms of maritime traffic," Suloff said. Also, many of the areas are dynamic because of earthquakes, silting, and hurricanes.

"Current technology would let us completely survey the sea floor," Suloff noted. Side-scanning sonar can provide accurate topography for larger areas than can be charted by a ship passing overhead with a depth sounder.

GPS enables accurate location of soundings. Geographic information systems allow collected data to support many requirements, like mapping, coastal planning, and research. Data for improved charts would enable mariners to start using the Electronic Chart Display Information System (Ecdis), which fuses electronic charts with real-time radar, GPS, and the Physical Oceanography Real Time System (Ports). Captains would be able to steer head up rather than hunched over charts. The International Maritime Organization is to set Ecdis standards in 1995.

C&GS has only five ships and two shore-based field parties with which to collect data. In 1994 it will investigate whether it can perform part of the surveys with the U.S. Army Corps of Engineers' Scanning Hydrographic Operational Airborne Lidar Survey (Shoals), a laser system that probes relatively clear water to a depth of 30–50 meters [see figure above]. Canada and Australia have been developing similar systems over the past 20 years. C&GS plans to request proposals for commercial mapping services and equipment in the coming year. ◆



Remapping U.S. coastal waters—primarily key harbors and their approaches—will be accomplished by the U.S. Coast & Geodetic Survey (C&GS) using light and sound. The Scanning Hydrographic Operational Airborne Lidar Survey (Shoals) will use the time delay from laser pulses to measure water depth. It is limited to relatively clear, sediment-free waters, but can chart large areas faster than conventional methods. The bulk of the C&GS survey will be accomplished by ships with sonar mounted on the hull and on towed, unmanned submersibles. The ships also measure salinity, temperature, and other factors. In both cases, Navstar satellites are used to determine position.

Aerospace and military

The industry is still reeling from defense and aerospace cutbacks as well as from several space failures. Bright spots were the success of the DC-X demonstration vehicle and the joining of the U.S. and Russian space station programs.

Encouragingly enough, U.S. defense contractors have submitted 2800 proposals totaling US $8.5 billion in pursuit of $324 million worth of projects under the Department of Defense's Technology Reinvestment Program. Announced by President Bill Clinton in March, it will provide Federal funding, matched by private capital, to convert defense development and production capabilities to civilian missions, as well as preserve crucial capabilities.

First winners were announced in October 1993. The program also involves the National Aeronautics and Space Administration (NASA), the National Science Foundation, and the departments of Energy, Commerce, and Transportation.

A review of defense spending, priorities, and threats established that the United States should maintain its capability to fight two major regional conflicts while reducing spending. The Air Force will fall back from 28 to 20 fighter wings and from 787 to 500 strategic missiles, while the Navy will trim 14 to 12 aircraft-carrier battle groups and 22 to 18 ballistic missile submarines. Their next-generation fighters and dozens of military bases were slated for closure or consolidation. Meanwhile, Britain announced hefty cuts, including an end to an air defense missile system put at UK £500 million.

The U.S. Navy revealed the existence of the USS Sea Shadow, a 49-meter catamaran test ship that uses stealth technology.

STAR WARS NO MORE. The United States' Star Wars program officially ended after 10 years and $30 billion worth of research. The Strategic Defense Initiative Organization (SDIO) became the Ballistic Missile Defense Organization (BMDO) on May 13 and was refocused on ground-based missile interceptors. In addition, the Clinton administration decided on a narrow interpretation of the 1972 Antiballistic Missile Treaty as allowing only 100 fixed, ground-based interceptors.

In August, *The New York Times* claimed that a key SDIO test had been rigged to fool the U.S. Congress and the Soviet military. In 1984 the fourth Homing Overlay Experiment (HOE) scored the first head-to-head destruction of a missile.

Citing an unnamed source, the newspaper alleged that the target had carried a homing beacon and had been heated to make it appear brighter to HOE's infrared seeker. An investigation concluded that a deception had been planned but not implemented. The target was heated to match Soviet warheads, and its beacon could be received only by ground stations.

THAAD ADVANCES. The U.S. Army Missile Command (Micom), Huntsville, Ala., kept to an ambitious schedule in developing and testing the Theater High Altitude Area Defense (Thaad) missile interceptor with 20 test flights during 1994–96. The initial design was approved, and full-scale wind-tunnel tests simulated its kill vehicle separation. In addition, said deputy project manager Paul Lynch, "we have done a tremendous amount of development of a hardware-in-the-loop simulation facility to bring everything together in preparation to check out the software." First flight is expected by September, and the first intercept in January 1995. The program has attracted the attention of Japan, which is increasingly worried about North Korea's capabilities.

Shrinking defense budgets will force the Defense Acquisition Board to choose in February between two shorter-range missile interceptors, Patriot's PAC-3 upgrade and the Extended Range Interceptor. Germany is helping to develop Patriot PAC-3's 20-GHz multimode seeker and the sophisticated warhead fuzing.

TAILSPIN. In an unprecedented move on April 30, U.S. Defense Secretary Les Aspin reacted to the mismanagement of the C-17 cargo jet project by disciplining three top officials and firing a fourth, Major General Michael J. Butchko, commander of the Air Force Development Test Center, Eglin Air Force Base, Fla.

In initial test flights, the C-17 did not meet several key requirements, and its flaps melted in the engine exhaust. The $8 billion project is more than $1 billion over budget.

In January, *Jane's Defence Weekly* claimed that the National Aerospace Plane (NASP) was really a front for "Aurora," a secret spy plane that flies at Mach 8 and an altitude of 40 to 50 km and uses liquid methane as fuel.

ARMS CONTROL. South Africa admitted it once had six 20-kiloton nuclear weapons, but dismantled them in 1990 and submitted to inspection by the International Atomic Energy Agency (IAEA), Vienna, Austria. "This is the first case of a country completely rolling back its nuclear arsenal," said analyst Jon Wolfsthal of the Arms Control Association, Washington, D.C.

North Korea refused to let IAEA inspect two nuclear facilities suspected of concealing plutonium. In response, Japanese Foreign Minister Kabun Muto said in July that his nation must be ready to develop its own nuclear weapons. Under U.S. pressure, Russia withdrew an offer to sell cryogenic rocket technology to India. U.S. officials feared it would be applied in India's atomic weapons program.

PLANE PRODUCTIDN. The aircraft industry remained fragile as layoffs and cuts continued. "By the end of [1993] we will have lost 30 percent of the workforce that we had in 1989," said Don Fuqua, director of the Aerospace Industries Association, Washington, D.C. Most layoffs are in middle management and reflect decentralization.

Boeing Co., Seattle, citing the slump in aircraft orders, will release 28 000 persons by the end of 1994, bringing its workforce down to 110 000. Boeing also reduced its expectation of aircraft purchases for the next 17 years: it forecast that the industry would deliver 12 000 airframes worth $815 billion (down from $850 billion in 1992) by 2010, and that the demand for jumbo jets would decline in favor of smaller fuel-efficient models.

"We are hoping to see a turnaround," Fuqua continued. "We thought that it would be in orders for the 1996 timeframe," which would affect employment today.

Fuqua said partnerships are being formed to pursue large projects that would once have been the domain of single companies. McDonnell Douglas Corp., St. Louis, is looking for an international partner for a new 600- to 700-passenger jumbo jet. Boeing announced last January that it would team with four European firms to design and build an 800-passenger jumbo jet. Fuqua also expects a consortium would form to develop the proposed High-Speed Civil Transport.

HIGHLIGHTS

- U.S., Russian space station programs unite
- Tech Reinvestment Program welcomed
- Telerobots tackle remote terrain, volcano
- NASA repairs Hubble in space

Dave Dooling Contributing Editor

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Pratt & Whitney

Four Pratt & Whitney RL10A-5 engines power the DC-X advanced technology demonstration vehicle. Each can be throttled from 19 400 to 64 800 newtons of thrust. An operational DC-Y would require eight larger engines with nozzles that can be extended; only four would be needed for landing.

After one year of listening for signs of civilization, NASA's search for extraterrestrial intelligence (SETI) had the plug pulled. The High Resolution Microwave Survey (HRMS) used high-density multichannel spectral analyzers to sift through manmade signals and interstellar noise for signs of technologically advanced civilizations.

The nine-year project involved a targeted search of nearby sunlike stars in the 1–3-GHz band (200 hours completed) and an all-sky survey in the 1–10-GHz band (60 regions scanned at 8 GHz). A late amendment by Congress to the 1994 appropriations for NASA forced the shutdown of SETI on Oct. 12, 1993.

"It's done," said Jill Tarter, project scientist at NASA's Ames Research Center, Mountain View, Calif. "NASA is out of this business." She is looking for private funding—$3 million a year—to continue the program at the nonprofit SETI Institute, Mountain View, Calif.

ROBBIE STEPS OUT. Prototypes of robotic planetary explorers took several small steps forward. In late August, engineers at McDonnell Douglas Astronautics Co., Huntington Beach, Calif., teamed with Russian counterparts to operate a Marsokhod rover, said John Garvey of McDonnell Douglas; it has an advanced chassis and suspension system. The engineers viewed stereo images transmitted at 2400 baud via Inmarsat as they drove Marsokhod up to 30 meters a day across the rugged Khamchatka Peninsula for five days.

On Jan. 1, 1993, NASA's Goddard Space Flight Center, Greenbelt, Md., tried to send the 400-kg, spiderlike Dante robot on a 200-meter tour of the inferno at the edge of a lake atop Mount Erebus, Antarctica's only active volcano. Dante, teleoperated via satellite, had moved only 7.3 meters when its optical-fiber link to the relay station broke. In November, NASA succeeded in a different test with a teleoperated submersible exploring the waters beneath the Ross Ice Shelf.

SPACE STATION REDUX. After spending $11.2 billion in nine years, NASA was directed by President Clinton to redesign Space Station Freedom again to reduce its projected original $30 billion cost by as much as $9 billion. The order came just as NASA was completing its critical design review before starting construction. NASA put Johnson Space Center, Houston, Texas, in charge, made Boeing Space and Defense Group, Huntsville, Ala., the prime contractor, and moved to close the Reston, Va., program office. (Even the name, Freedom, was dropped; some wags suggested that the scaled-back project be given the shortened name of Fred.) Previously, four NASA centers and four prime contractors ran the program. More than 4000 layoffs were expected.

Clinton eventually selected a blend of the two options that could be launched by the year 2001 for $10.5 billion. The space station would retain elements of the original design but have a crew of only four instead of eight, and use Russia's durable Soyuz spacecraft as a lifeboat.

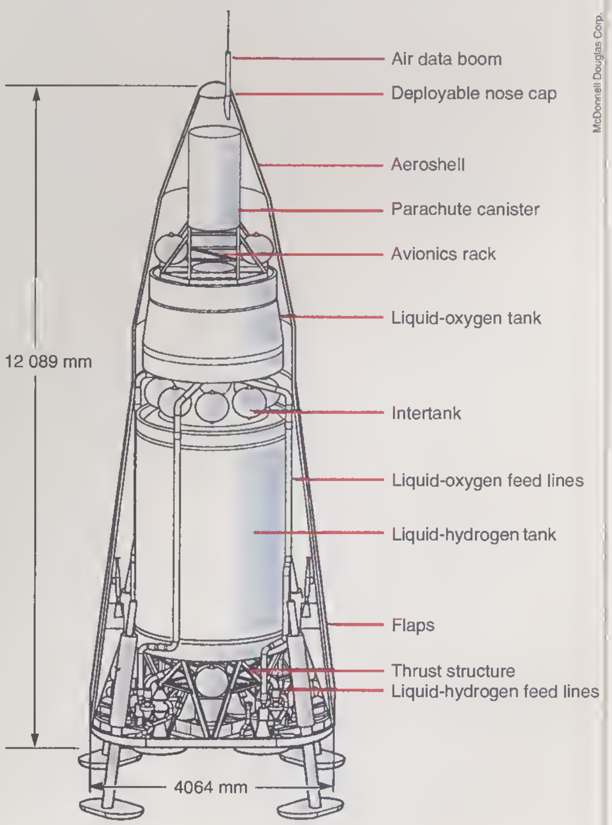
In November, NASA and Russia announced plans to use Mir 2 as the starting point of the international space station. The station will be placed in a high-inclination orbit that can be reached by Russian and U.S. launchers. As a prelude, NASA now plans up to 10 shuttle missions to the Mir 1 station during 1995 through 1997, when Mir is to be retired. U.S. astronauts will conduct extended experiments aboard Mir during that time.

NASA Administrator Dan Goldin urged the House space subcommittee, "We cannot turn our back on Russia now. We cannot respond by counting beans and being afraid to take risks. It'd be easy to turn our backs, but we have a window of opportunity now that will close for two to three decades."

The European Space Agency (ESA) was taking a cautious approach: "Everything is still in the mixer," said Ian Pryke, the agency's Washington, D.C., representative. "We haven't agreed to involve the Russians. We have agreed to look at it." ESA has also canceled its Hermes spaceplane project and moved to make its own Columbus program less dependent on the U.S. program.

NASA also faced the possibility of closures. By spring, it should finish studying major changes in missions and responsibilities that would strengthen Johnson Space Center, severely reduce the size of Marshall Space Flight Center, Huntsville, Ala., and close Wallops Flight Facility, Wallops Island, Va.

HOUSE CALL IN SPACE. The year's main event in manned space activities was the STS-61 space shuttle mission to repair the Hubble Space Telescope last December. Hubble's 2.8-meter primary mirror has spherical aberration that keeps it from focusing sharp images. Routine maintenance is part of Hubble's design, but this first service call turned into a marathon involving five six-hour spacewalks by two pairs of astronauts. Their



McDonnell Douglas Corp.

The prototype single-stage-to-orbit DC-X is only 12 meters tall and 4.1 meters across the base, and weighs 10 300 kg at landing after burning almost 8500 kg of propellant. A full-scale DC-Y would stand 38 meters tall and weigh 580 300 kg. It would carry a 9100-kg payload between the liquid oxygen and hydrogen tanks, and would not have the parachute canister.

main job was to install a new Wide Field/Planetary Camera with its mirrors reshaped to cancel the primary mirror's aberration and with small relay mirrors using piezoelectric ceramic mounts to ensure alignment.

In addition, the crew replaced a science instrument the size of a phone booth with the Corrective Optics-Space Telescope Axial Replacement (Costar). Its five pairs of mirrors will reshape light entering the other three science instruments. Also repaired were solar arrays that "twang" from thermal stress, hiccupping gyroscopes, and failing computer memory. Astronauts used virtual reality computers to rehearse many of the procedures while still on the ground.

Other 1993 shuttle missions launched the Advanced Communications Technology Satellite for the first broad tests of 20-GHz–band communications and the sixth Tracking and Data Relay Satellite; they carried only three Spacelab missions. The commercial Spacehab was introduced on the Shuttle's June flight, which also retrieved the European Space Agency's Eureca satellite launched in 1992.

The United States was embarrassed by the loss of five satellites, including a Navy communications satellite, an ocean surveillance satellite, and Landsat 6 during launch. Mars Observer and the NOAA-11 weather satellite both went silent on Aug. 21, apparently due to faulty master event timer transistors that came from the same lot. The space shuttle's main engines received only a "passing" grade from a National Research Council review, and Congress canceled the planned Advanced Solid Rocket Motor, which would have increased shuttle payloads; but motor design problems stretched the schedule so that it would have become available only after completion of most of the work on the space station, which needed it most, had been done.

Thinking small is becoming attractive as budgets decline and individual failures become too costly. In January, the BMDO will

GREENWOOD: Transformation from defense to commercial cannot be total

VIEWPOINT

The world's aerospace and defense communities already have faced difficult times, but the real challenge lies ahead. With continued budget reductions projected for the future, a good many industrial nations must convert sectors of their aerospace and military industries to civilian markets, must downsize excess capacity, and must make operations more efficient and responsive to changing needs.

Converting technologies across boundaries—especially from defense to commercial applications—has been difficult in the past. As with any market, especially commercial, customer demands and expectations are different, delivery is critical, and reliability and cost become differentiators. Understanding and crossing these barriers has not been easy for companies and laboratories raised in the protective environment of government-supported R&D.

The transformation from defense to commercial cannot be total; every nation must maintain an adequate defense base to meet evolving challenges. Even as many recent events have reduced tensions, new threats to world stability are emerging. Naturally, suitable strategies and policies are only just beginning to evolve.

But, while the new U.S. administration's priorities are being debated, the Federal budget is requiring major reductions in forces as well as changes in—or cancellation of—development and acquisition programs. As a result, U.S. industry cannot predict the outcome of the current turmoil and whether it will help maintain national security in a vibrant and balanced way.

One change that is clearly evident is an increased emphasis by the National Aeronautics and Space Administration (NASA) and the Department of Defense on performance: the production of a quality product on time and within budget.

This raises the concern that program developers may become too conservative in implementing new technologies. But the risks that innovation involves are essential to advancing the state of the art and meeting new requirements. To ensure that new technology programs meet cost and schedule constraints, risk management must be applied systematically to define potential problems and to devise timely plans for dealing with them.

Problems abound. NASA has experienced a year of turmoil while redefining the space station, making major management changes, and completing yet another roles and missions study. It is to be hoped that the debates end quickly so the agency is able to move ahead with the space station, complete several key missions, and focus on program implementation.

The loss of several spacecraft last year remains a grave disappointment. As in the past, we will learn to understand and eliminate the cause of such mishaps. But space remains a risky business, and continued improvements in processes and procedures are required.

'We may become too conservative in implementing new technologies, but the risks that innovation involves are essential...to meeting new requirements'

One suggestion is to use surplus military missiles to launch "smallsats" and "microsats." Unfettered use of surplus missiles could, however, damage the U.S. launch industry significantly at a time when it should ensure that commercial and government users have low-cost access to space and that the launch industry remains internationally competitive. Smallsats have great scientific potential, but cannot substitute for simultaneous measurements collected by platforms such as the Upper Atmospheric Research Satellite or the Earth Observing System (EOS). They should be applied to specific, well-defined scientific objectives consistent with the reduced capabilities of smaller platforms and payloads.

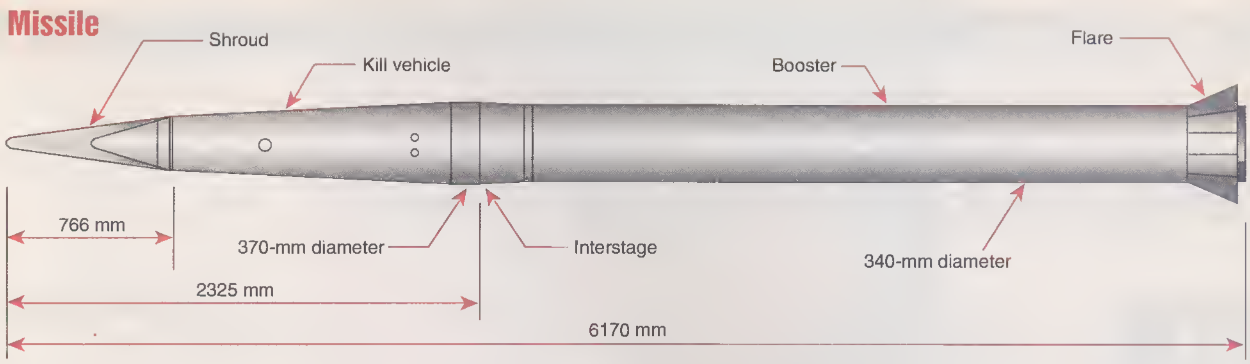
EOS, a signal advance in the study of our planet, will involve hundreds of scientists around the world. Here an opportunity exists to recapture public interest in space by aggressively applying data from EOS and other missions to terrestrial problems. As engineering extends science from the laboratory to the realm of the practical, space applications can focus on using its mass of space data to help deal with flooding, food yields, environmental monitoring, and forestry management.

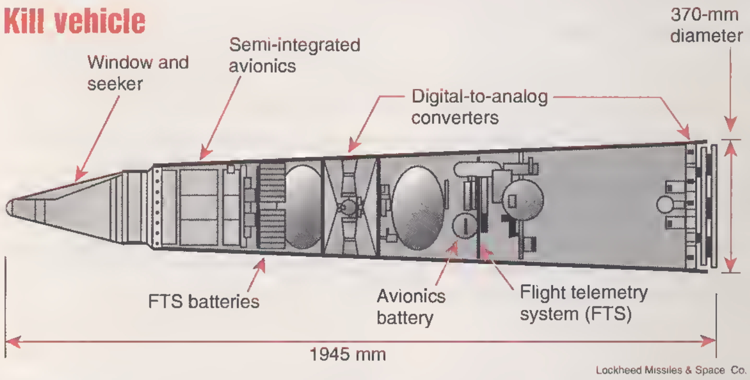
Understanding our planet's environment is critical; managing and utilizing our terrestrial resources is equally important. Space agencies around the world should expand their activities in space applications and demonstrate near-term payoffs that every citizen can appreciate. The payoff in the next decade will surely come from new observing platforms, but probably more important will be the advances in information technology. We have only barely begun to analyze and understand our data.

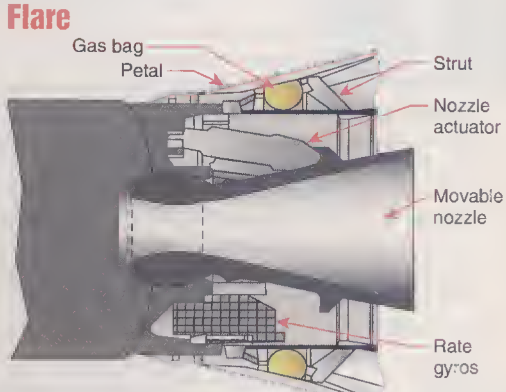
In recent decades defense and space programs have sparked a national commitment to education, especially in improved instruction in mathematics, science, and engineering. As we cope with the worldwide loss of opportunities for engineers and scientists, retaining public interest in space and defense is important.

Massive defense and space budget reductions and Congress' reluctance to fund the space station—even the cancellation of the search for extraterrestrial intelligence—may lead students to think that no one wants to invest in the future. Aerospace and defense still offer unique opportunities for young people to work on challenging and interesting problems such as the analysis of our vast data sets. We must keep attracting the bright minds of our youth because they are the world's future.

Lawrence R. Greenwood is president and chief operating officer of Nichols Research Corp., Huntsville, Ala., and a former vice president and general manager of what once was GE Astro-Space Division, now a unit of Martin Marietta Corp.







Thaad missiles are to destroy incoming warheads with a direct hit rather than explosives. After a single-stage boost, the rocket motor and nose cone are discarded to make the kill vehicle more agile in the last 10 seconds of engagement. A platinum-silicon focal plane array behind a sapphire window homes on the target's infrared signature.

launch Clementine, a small probe loaded with miniature missile sensors; they will be tested while orbiting the moon and then flying past an asteroid. NASA is contracting with the Universities Space Research Association, Washington, D.C., to develop and launch three small science satellites for less than $24 million, thanks to the use of surplus ballistic missiles, a controversial approach.

In March the 100-kg Alexis-1 satellite was lofted by a Pegasus rocket carried by a cargo jet. Alexis-1, built by the Los Alamos (N.M.) National Laboratories, conducted X-ray astronomy and nuclear monitoring tests.

The International Small Satellite Organization, Washington, D.C., claims small satellites can provide innovative communications services at costs competitive with larger systems. Constellations of small, low-orbit satellites—versus geostationary orbit at 36 000 km—can support communications in packets or for mobile phones and remote users [see "Telecommunications," pp. 22–25]. Remote sensing is perceived as another growth area for smallsats, to fill gaps of the kind caused by the loss of Landsat 6.

THE RUSSIANS ARE COMING. Several Western companies acquired the rights to market Russian rocket engines, but politics and money may determine whether they are used. Although the inner workings of the Russian space program are still not fully known, "the launch records speak for themselves," observed David R. Stone, program manager for vehicle systems in NASA's Office of Advanced Concepts and Technology. Several companies have deals to market engines, while Lockheed Missiles & Space Co., Sunnyvale, Calif., and Krunichev Enterprise, Moscow, formed Lockheed-Krunichev International to market the Proton launch vehicle. Even if opposition to buying foreign systems is overcome, integrating Russian engines into a U.S. launcher could cost tens of millions of dollars. For fiscal 1994, Congress passed only a tenth of the $400 million the industry claims is needed to upgrade existing U.S. vehicles.

According to Grigory Khozin of the University of Alabama in Huntsville, a former science and technology policy specialist at Moscow State University, many deals between U.S. and Russian companies have been made possible by the confusion surrounding the Russian government's reorganization. Khozin said that the Russian government on June 29, 1993, passed "the first space law in Russian history, which somehow tries to characterize the activities of participants and their activities." Much of what is happening is a reshuffling of old military and industry ministries. A key shortfall is a lack of professional staffs to advise Russian President Boris Yeltsin and parliamentary committees.

NEXT STOP, ORBIT? Modest suborbital hops by the DC-X seemed to point the way to the future, though. DC-X is the advanced technology demonstration vehicle built by McDonnell Douglas for the BMDO's Single-Stage Rocket Technology Project.

BMDO started the project in 1991 to develop a robust, flexible launch system free of the problems that plague conventional launchers. "The key point, in addition to demonstrating vertical takeoff and vertical landing and controllability, has been designing it to operate like an airplane in terms of operability and supportability," said McDonnell Douglas program manager Paul Klevatt. "We have shown that we can indeed reduce the manpower" needed to launch an orbital vehicle. DC-X is operated by three people in a control van near the launch pad.

"We also proved that rapid prototyping does work in terms of starting with a fresh sheet of paper," he said. Less than two years passed from contract to launch. Among the DC-X's advances was 30 000 lines of Ada coding rapidly developed by Integrated Systems Inc., Santa Clara, Calif.

DC-X's modest first flight on Sept. 11 lasted just 72 seconds. It rose 91 meters, moved 107 meters sideways, and landed on four deployable legs. Subsequent flights increased altitude and dynamic pressure; each landing was within a meter of the aim point. The last flights—to 8.5-km altitude and using data from Global Positioning System satellites—were canceled at the last moment by cuts in the 1994 defense budget. BMDO had proposed a DC-X2 suborbital demonstrator that would climb to 160 km. NASA has formed an X-2000 team to investigate similar designs and technologies for a new class of launch vehicles. ◆

Medical electronics

The quality and cost of health care is very much on the public's mind. In the United States, health care accounts for more than one-tenth of the gross domestic product and is still rising, prompting calls for reform and for a hard second look at medical technology. Worldwide, the use of medical devices is growing at nearly 10 percent per year, well above the rate of increase in most industrial sectors.

According to an IEEE poll of 1012 U.S. adults last September, health care is perceived as where technology will affect them most in the next 10 years. (Forty-two percent gave that reply, more than twice as many as nominated education, the runner-up with 17 percent, or communications or leisure.)

Engineers and physicians at the annual international conference of the IEEE Engineering in Medicine and Biology Society (EMBS), held in October in San Diego, Calif., explored not only the latest advances but also broad societal issues. They seemed to feel it urgent to collaborate on bringing health costs down while improving quality.

In addition, although quantitative measures of medical remedies and their outcomes have long been discussed, providers are finally beginning to take more methodical approaches to the problem. A November survey of 3300 hospitals by the American Hospital Association, Chicago, found that 69 percent have quality improvement initiatives, three-quarters of which were begun in the past two years. But it said that total quality management ran into many obstacles, such as inadequate health information systems and doctors' resistance.

According to Warren Grundfest, director of the Laser Research and Technology Development Center and assistant director for surgery at the Cedar-Sinai Medical Center in Los Angeles, reform is hampered by the lack of "outcomes data" on the cost and efficacy of treatments for patients and also by "medieval accounting practices."

There are many sides to the issue, of course, and technology is only one. But recent developments, from standardization to automated surgery and simulation, hold out some hope of improved care. The work is fraught with danger and things sometimes go awry, as evidenced recently by one medical manufacturer against whom a large fine was levied.

John A. Adam Senior Associate Editor

HIGHLIGHTS

- Wireless networks back up home care
- 3-D simulation helps surgeons
- Robot doctor may cut returns to hospital
- Breast cancer diagnosis improves

EUROPEAN STANDARDS. A few thousand general types of medical devices exist. When different versions and sizes of these devices are assessed, perhaps 40 000 variants exist on the market, said Maurice Freeman, a technical expert for medical devices at the Commission of the European Union (formerly Community), in Brussels, Belgium.

As the European Union accounts for about one-third of world consumption of medical devices, changes in laws there affect medical manufacturers worldwide, which is why discussion of the Union's new directives is such a popular topic at U.S. conferences.

The first directive, dealing with implantable medical devices that use electricity, came into force last January. The second, dealing with virtually everything else (and called the Medical Devices Directive) underwent the first reading last year and is expected to come into force next year. The third directive, on in vitro diagnostic medical devices, is at its first draft proposal stage.

The goal is to enable companies in the European Union to have a barrier-free home market, akin to that of U.S. companies, to reduce unit costs. To sell in Europe with an appropriate "CE mark" will mean conforming to certain procedures and standards such as the ISO 9000 series, and sometimes being approved by a certification authority. Some U.S. companies worry that national certification authorities of member states could impede access to markets. But needing only one approval to enter the entire Union market is generally seen as favorable to industry, no matter what the country of origin.

HOME CARE. Besides better standardization, another cost-cutting trend is to treat more patients at home rather than in hospital. A project by Carnegie Mellon University (CMU), Pittsburgh, has combined wireless data communication and laptop computers to help nurses provide better care at patients' homes.

A prototype nomadic computer system was devised by 19 graduate students working under Professor Alex Hills of CMU's Information Networking Institute. When connected by wireless to a network, it will allow nurses to receive doctors' orders, chart patients' progress, review medical reference books, and even show educational videos to patients.

The students did market research to assess what users in the home health care industry needed. (Several companies already offer low–bit-rate wireless data services.) With support from Bellcore, the CMU project devised high-speed wireless links over a wide area, using mathematical modeling of the technology of both cellular phones and wireless local-area networks. It was demonstrated in October. (Currently, high-speed wireless communication is installed in building sites only for local networks; other wide-area wireless services, if they exist, are rare.)

Further tests this year and next are planned by CMU to explore technical trade-offs, such as radio frequency bandwidth, cell size, processor speed, and two-way transmit speeds. Faster communications will make software downloading and the timely transfer of imagery more feasible.

Home care advocates should note a recent study by Stanley M. Finkelstein of the University of Minnesota, Minneapolis. In this experimental setup, lung transplant patients, who benefit from monthly checkups after surgery, can test themselves, record the results, and transmit them reliably from their homes. Not only may costs be cut, but daily tests (of blood pressure and "best blows" into a spirometer) could help detect trends before symptoms indicate a problem. All the measurements were performed daily, stored automatically, and transmitted weekly to a relational database.

Also thanks to software, it is now easier to peer through the skin and skull for diagnosis, brain surgery, and training. The images are combined into three-dimensional models manipulated by more powerful graphics computers. For instance, a doctor can now see the peculiarities of a person's brain and plan the best route to a tumor, so as to extract it with minimal damage to nearby tissue.

Last year surgeons at Brigham and Women's Hospital in Boston, with help from engineers from General Electric Co.'s imaging and visualization laboratory in Schenectady, N.Y., began such modeling work to assist operations in real time. As of early November, 17 operations had been performed with neurosurgeons glancing at a monitor.

Overlaid on a real-time video image of the patient's head was a magnetic resonance

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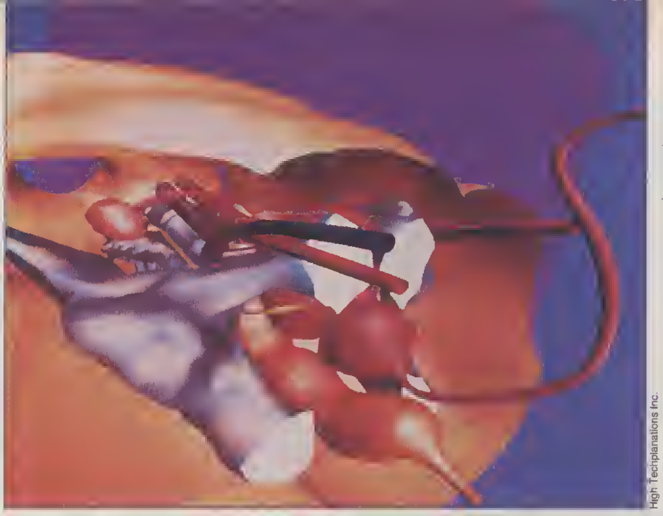

High Techplanations Inc.

Simulations like this one showing prostate surgery may seem more realistic to medical students than practicing with cadavers.

image taken previously. It gave the surgeons more information so they could "almost see into the patient," said William Wells, a researcher in the surgical planning laboratory at Brigham and Women's Hospital.

Prior to surgery, a model of a volunteer's brain is constructed by combining high-resolution "slices" from a GE magnetic resonance imaging (MRI) machine, a job that takes hours, noted Wells. With a few keystrokes, layers or sections of the digitized brain can be stripped off to show the white matter, highlighted sensitive areas like arteries, or the tumor. Stored MRI or computer tomography (CT) imagery is registered on the real imagery by sticking Vitamin E capsules on the head as markers.

Kirby Vosburgh, manager of the GE laboratory, calls the demonstration for surgeons "enhanced reality" and doubts that 3-D virtual reality would do any better. He said, however, that GE is working on real-time MRI and CT scans for the operating room. If that succeeds, surgeons could have high-quality views of the body's interior as they worked.

Demand for such services is being helped by minimally invasive surgery, such as endoscopy, where the doctor guides an optical-fiber light probe and tiny camera through the patient while looking at a video screen. Instruments are then inserted through puncture holes and manipulated from outside the body. A 3-D environment to utilize human depth perception might aid this work, as might some tactile feedback since often cancerous tissue is detected by touch.

Such hopes are spurring medical work in virtual reality (VR). Companies like Medical Media Systems, Hanover, N.H., hope to use VR in training surgeons in new techniques, much as pilots are trained for new planes on simulators. High Techplanations Inc., a Rockville, Md., firm supported by the big medical company Merck, expects to complete a surgical simulator for prostate laparoscopy within the next few months and plans to model the entire torso. GE is examining VR for endoscopic surgery but noted it is premature to assess its efficacy to the patient and the patient's bill. Georgia Institute of Technology in Atlanta is trying to simulate surgery on the human eye, complete with feedback on the force being exerted.

These 3-D simulations allow rather more realistic training than do cadavers, noted Jon Merrill, a physician and director of interactive media for High Techplanations. If a trainee pinches a nerve or slices through a blood vessel in a cadaver, nothing happens.

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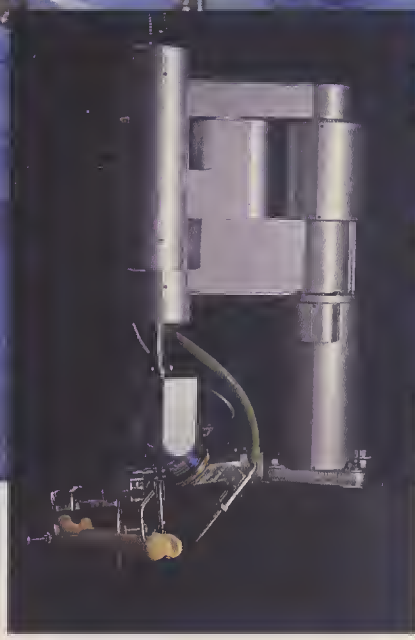


Full-scale tests of robot-assisted hip surgery on humans were authorized by the U.S. government last September. The robot mills a cavity into a bone [as shown in the inset] with greater precision than traditional milling with hand tools.

Dead tissue is usually harder, color is changed, and arteries no longer pulsate. Once something is cut in a cadaver (like a gall bladder), it cannot be reattached.

But in digital format, procedures can be repeated ad infinitum and stored for later group analysis. Some organs can also be made transparent, "crisis" drills can be created, and various types of gall bladders can be modeled.

AUTOMATED SURGERY. If patients already lament the assembly-line techniques of health care, how will they react to a robot doing surgery? A robotic surgical procedure has been developed for implanting artificial hips, and last September the U.S. Food and Drug Administration (FDA) authorized full-scale human clinical tests at several U.S. sites.

Using surgical cutting tools, Robodoc mills a cavity in the thigh bone to hold the prosthetic implant. Traditionally, surgeons would use reamers and mallets to prepare the cavity, a procedure that can often leave less than 50 percent of the prosthesis in contact with the bone. Tests with the robot on cadaver bones showed a 90 percent implant-to-bone contact.

Bela Musits, the company's president and a former IBM researcher, told *IEEE Spectrum* that Robodoc might in the long term alleviate some of the need for revision hip surgery, which each year accounts for a significant portion of total hip surgeries.

To guide the robot, three titanium pins are inserted into the patient's femur. (Eventually, Musits hopes to register the robot to the patient's anatomy without the pins.) Next a CT scan is taken and read into Robodoc's preoperative planning workstation, called Orthodoc. The 3-D images of the implant and femur are precisely matched, and the data is transferred to the robot's computer.

Once in the operating room, the surgeon prepares the patient in the traditional manner, exposing and sectioning the top of the femur bone before securing it in the clamplike bone fixator. The surgeon enables Robodoc to orient itself by letting the robot arm gently touch the heads of the titanium pins. The robot then mills the cavity in the upper part of the femur to accept the prosthesis.

Sensors check the robot's position and detect the forces on the cutting head, so that if the machine deviates from the planned movements, work will stop. Also, redundant processors must agree with each other for the robot to proceed, and a surgeon must approve each step of the operation.

The Robodoc Surgical Assistant is a modified Sankyo Seiki custom five-axis robot, mounted on a mobile base and equipped with a force sensor, bone motion monitor, and custom pneumatic surgical tools. An Orthodoc Preoperative Planning Workstation uses proprietary 3-D software on an IBM RS/6000 workstation, a high-resolution monitor for 3-D bone and implant images, and an optional CT scan tape reader. An operating room monitor displays messages and surgical simulation.

Robodoc has assisted in 10 operations on people, as well as others on dogs in a prior limited study to establish system and operating design parameters and efficacy. Until recently, surgical robots were used only to aim tools.

BREAST DIAGNOSIS. A special Presidential Commission on Breast Cancer estimated in October that two million women in the United States alone will be diagnosed with breast cancer during the 1990s and 460 000 will die from it. Breast cancer has been one of the nation's fastest-growing major diseases. Since 1950, its incidence has increased 53 percent.

Better detection in mammography was a highlight of the IEEE EMBS conference. The breast itself is a "complex architecture"

EBERHART: Enough is enough

VIEWPOINT

Our health care costs too much and delivers too little. Why is that? I certainly don't have all the answers, but I believe I can identify a major contributing factor. We engineers are constantly developing better medical devices. And the price of these devices, which is skyrocketing, contributes heavily to health care costs. Is it the sophistication of the devices that drives up the cost? I think not.

The advent of the integrated circuit made it possible to fabricate sophisticated electronics on chips for a few dollars each in large quantities. Software for these devices, while more and more expensive, still does not account for their cost. What makes these devices cost so much is that we insist they be made foolproof and perfect. We also insist that they last "forever," in the sense that their malfunction must not contribute significantly to the death of any patient.

This obsession with perfection is destructive for at least three reasons. First, perfection is unattainable, and having it as a pseudorequirement is driving the costs of development, testing, and clinical trials through the roof. (I use the term "pseudo requirement" because regulatory organizations often pretend that perfection is a requirement, and manufacturers must then pretend to have achieved it.) Second, it is unnecessarily delaying the availability of technology that could enhance the quality of life. Third, it is draining the resources of our health care regulatory agencies worldwide, and preventing them from focusing on the very real (but relatively few) problems of malfeasance on the part of manufacturers.

The first successful implantation of a heart pacemaker in a human occurred in 1960. In the mid-1960s, because of battery limitations, pacemaker operating lifetime was generally less than two years, during which time 5–10 percent of the pacemakers had circuit failures. According to the October 1981 *IEEE Spectrum*, pacemaker failure rate by 1978 had dropped to "less than or equal to 0.15 percent per device for each month of use," and 81 percent of the devices implanted were expected to survive for 12 years. By 1981, about 200 000 pacemakers from one manufacturer indicated a circuit failure rate of less than 0.005 percent per month.

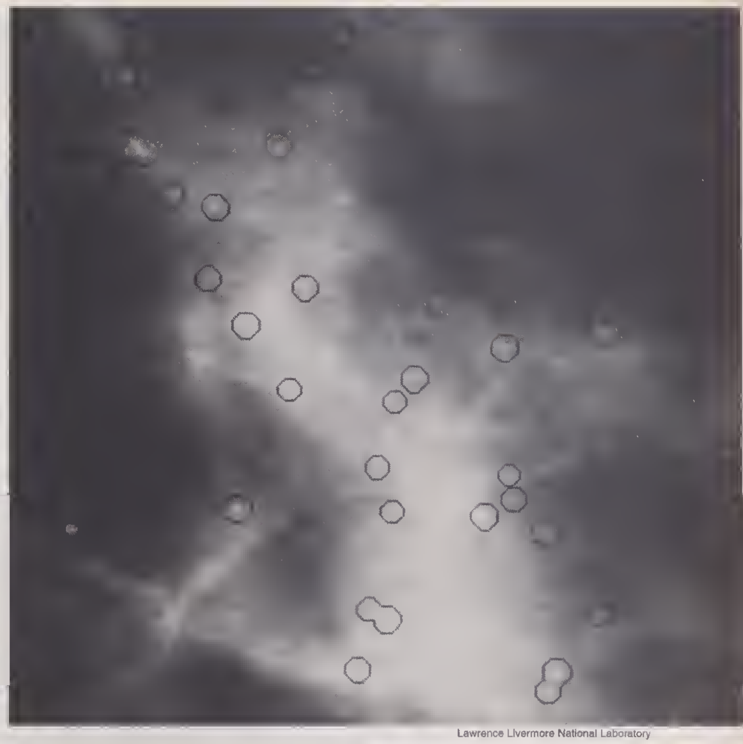
'Regulatory organizations often pretend that perfection is a requirement, and manufacturers must then pretend to have achieved it'

At least two things are important to note from the pacemaker experience. First, the device provided a benefit to humankind from the day it was introduced into the market. Second, it is unlikely that the original pacemaker, given its initial performance (and failure rate), would pass muster today. It took at least a decade before it met the standards typically imposed on new devices today, but it still provided obvious benefits and its performance steadily improved.

So what should we do? Above all, we need to quit focusing on achieving immediate perfection. Instead, we should concentrate on the likely benefits, the expected risks, and their consequences to the patient. Does the proposed device extend life or enhance the quality of life? Is it cost effective at achieving the purpose for which it was designed? We must stop supporting the utopian quest (supported by the legal profession) for a near-zero-percent failure rate from the moment a new device is introduced. For example, failure rates of significantly less than 1 percent per year should be acceptable in devices expected to add an average of at least 10 years to patients' lives.

Right now they are not. Such devices are being recalled, amidst sound and fury and lawsuits, every day. And legal settlements have become the largest single cost associated with many of these devices. Every manufacturer must anticipate legal settlement costs or go broke. We must reverse this trend, or the situation will only get worse. Of course, the public must be protected from misrepresentation and fraud, but we must face reality, which includes the fact that any electromechanical device, no matter how well designed and fabricated, may fail. We must focus on improving the quality of life.

Russell C. Eberhart is director of biomedical engineering at Research Triangle Institute, Research Triangle Park, N.C.



Lawrence Livermore National Laboratory

A digitized mammogram [left] undergoes several steps before a computer algorithm circles the areas [right] containing likely microcalcifications that are potentially cancerous. Two types of high-frequency analysis are employed by the algorithm.

of fat and soft tissue, said Carl Vyborny of the University of Chicago, Illinois. By the time a cancer is big enough to be felt as a lump, it has been growing for an average of 10 years. Key to early diagnosis is spotting significant microcalcifications, features sometimes as small as 0.1 millimeter. In fact, Vyborny noted, even huge cancers the size of a tennis ball are often "not all that obvious" to many radiologists, who in the course of a day may become tired or distracted.

There are also problems with false positives: only about 20 percent of biopsies ordered show cancer. False negatives are even more of a concern. A 1992 study at the University of North Carolina, Chapel Hill, by R.E. Bird, one of the preeminent U.S. radiologists using the best techniques, showed that 77 of 320 cancer cases were evident in retrospect from their X-rays.

Better imaging and automated analysis might improve diagnosis. The quality of a mammogram is determined in part by the voltage that generates X-rays. A clinician bases the voltage on an X-ray unit on the thickness and tissue density of the breast. Determining appropriate voltage is still more an art, since existing noninvasive voltage measurements for mammography are accurate to within 1 or 2 kilovolts. Image quality, however, is influenced by subkilovolt changes.

A 46-cm-long diffraction spectrometer invented by Richard Deslattes at the National Institute of Standards and Technology, Gaithersburg, Md., promises much more accurate measurements for calibration, according to R. Edward Hendrick, chairman of the American College of Radiology (ACR) Committee on Mammography Quality Assurance. A patent for the device was recently issued and a license for commercial manufacture is presently pending.

Many universities are developing automated analysis techniques for mammograms. Lawrence Livermore National Laboratory, Livermore, Calif., developed an algorithm to detect microcalcifications in digitized mammograms. Initial results were mixed. Sometimes the algorithm produced too many false alarms, but it also identified microcalcifications missed by an experienced radiologist.

Work continues on a classification system to distinguish between suspicious and innocuous microcalcifications as well as normal background artifacts. The hope, said researcher Laura N. Mascio, is to produce a useful "computerized mammographer's associate" to transfer to a medical imaging company.

FDA CRACKDOWN. The medical industry often complains about the FDA's delays in granting approval of new products, and sometimes new product approvals fail to guard against unacceptable risks to patients. In October, the FDA's biggest ever investigation into health care fraud ended with one of the world's largest medical device manufacturers pleading guilty to more than 390 counts of fraud and human experimentation.

The company, C.R. Bard Inc., Murray Hill, N.J., produced heart catheters that resulted in at least one death and 22 emergency heart surgeries. The billion-dollar company agreed to pay $61 million in fines, or almost all of its 1992 profits. It will be monitored for four years by an outside consultant reporting to the FDA.

The catheter, a tube inserted into an artery, is supposed to make heart surgery unnecessary. By means of a balloon tip or a tiny rotary blade, the catheter either compresses or cuts out the plaque clogging the walls of arteries that nourish the heart muscle. The technique is called angioplasty. Animal studies showed, however, that the rotary blade catheter cut into artery walls only 50 percent of the time, data that the FDA charged Bard with concealing.

The number of angioplasties jumped ninefold between 1980, when the device was introduced, and 1990. Bard monopolized the U.S. balloon catheter market until 1985, when other companies introduced catheters with new features. The National Heart, Lung, and Blood Institute reported that nearly 300 000 of the procedures were performed in the United States in 1991.

According to the indictments, an entire plant, never inspected or approved, had been hidden from the FDA. FDA Commissioner David A. Kessler lambasted the company for "using unsuspecting patients as guinea pigs and operating rooms as laboratories."

Meanwhile, in November the FDA proposed to extend its regulations on medical devices back to the design stage. The agency estimated the new rules would cost the industry about US $85 million annually, but would prevent 53 deaths and 1150 serious injuries each year. Besides the risk of the rules stifling innovation, a spokesman for the Health Industry Manufacturers Association, Washington, D.C., said they "could be a significant extra burden." As the adjoining expert opinion suggests, the expectation of risk-free medical devices can actually be harmful to public health. ◆

Industrial electronics

Mounting pressures for improved productivity and efficiency in manufacturing, together with the constant need to cut costs, are making industrial electronic products and systems more important than ever. New hardware and software—industrial robots, machine vision systems, X-ray inspection systems, programmable logic controllers, fuzzy logic, neural networks, and power electronics systems—not only help companies achieve these almost universal goals but also assist in reducing pollution.

Particularly in Japan, industrial robots remain in demand. According to the Aug. 2 *Nikkei Weekly*, the Japan Industrial Robot Association estimated that the market for Japanese-made units could reach almost ¥460 billion (US $4.27 billion) in 1993, up 8.2 percent from the previous year. The increase is attributed, at least in part, to the introduction of robots in such nontraditional areas as civil engineering, among others.

Ongoing research on multisensor-controlled autonomous mobile robots indicates a lively interest in the idea of using automated guided vehicles to handle materials in the course of computer-integrated manufacturing. Meanwhile, robot navigation and intelligent sensors were among the themes addressed at Iecon '93, the 19th International Conference on Industrial Electronics, Control, and Instrumentation, held last November in Maui, Hawaii.

MACHINE VISION ON PC. One important tool for product quality in manufacturing—machine vision—took a sizable step forward in the shape of the Cognex 5000, from Cognex Corp., Needham, Mass. The product is the first advanced machine vision system on a card that can be plugged into personal computers (albeit only those with an AT bus). It relies on two powerful coprocessor chips: the company's VC-1 and VC-2, with highly efficient image-processing algorithms. The VC-2, for example, performs Sobel edge detection at frame rate, a computation critical to detecting edges in images being filtered. With its own frame grabber, on-board processor, and memory dedicated to vision processing, Cognex 5000 frees the personal computer to perform other control and processing tasks.

Gadi Kaplan Senior Technical Editor

HIGHLIGHTS

- **Machine vision plugs into a PC**
- **Data exchange standard impacts users**
- **Fuzzy logic ties up with PID control**
- **Neural networks put dent in emissions**

Research on machine vision flourishes the world over, as several Iecon '93 sessions indicated. Workers at such institutions as the Massachusetts Institute of Technology, Portugal's University of Porto, and the University of Tokyo and several other Japanese universities are vigorously exploring three-dimensional vision systems. Researchers at Tohoku University, Japan, for example, are developing a very large-scale integrated processor for 3-D object recognition.

Machine vision systems that inspect the quality of solder joints on printed-circuit boards are being improved, particularly for surface-mount technology (SMT), where defects are hard to identify because components lie so close together. Two competing San Diego–based companies—IRT Corp. and Four Pi Systems, a subsidiary of Hewlett-Packard Co.—added to their lines of X-ray-based inspection systems. An automated process monitor from IRT Corp., the CXI-3600, analyzes images up to 50 percent faster than its predecessor, the CXI-3300, by using Motorola 68040 single-board computers in a parallel multitasking mode. Other features are in-line operation and improved communications. The board moves on a conveyor belt into the IRT system after reflow soldering and onward to the next stage in automated assembly. The CXI-3600 allows data transfer over an Ethernet network for such purposes as statistical process control.

As for Four Pi Systems' 5DX series of automated process test systems, these cross-sectional X-ray imaging units can measure solder joints with a repeatability of within 2.5 micrometers, versus about 4 μm in the earlier 3DX Series 3500G system, according to Bruce Bolliger, the company's vice president for marketing. The motion control electronics have been improved with an adjustable board-positioning accelerator, which together with a reduced–instruction-set computing (RISC) processor ensure that images are acquired at a rate of four per second, as opposed to three for the 3DX Series 3500G. Yet the new system is simpler, having a less complex mechanical system and a single-bus computer architecture that eliminates more than a hundred of the older design's cables and connectors. So it sells for about two-thirds the price of its predecessor—about $370 000.

MARCHING IN STEP. A strong stimulus to less costly manufacturing will undoubtedly come from the emerging international Standard for the Exchange of Product model data (STEP). As its name suggests, this standardizes the way product data is modeled, so that organizations with different computers and application software may exchange such data freely. The standard will apply to all critical specifications—such as shape, material, tolerance, functional description, and product structure—throughout a product's life cycle, including disposal. Besides giving a big boost to transnational concurrent engineering, the standard will streamline design and manufacturing practices within companies that use incompatible computer platforms and software. STEP is by now a unanimously approved draft international standard and should win the full endorsement of the Geneva-based International Organization for Standardization early this year.

Such industry leaders as ABB Asea Brown Boveri Ltd., Zurich, Switzerland, have recognized STEP's importance in their own work ["Concurrent engineering," *IEEE Spectrum*, September 1993, p. 56]. In the United States, Ford Motor Co.'s Powertrain Operations, Dearborn, Mich., and the U.S. Department of Energy's Allied Signal Kansas City plant have used STEP to design and build an engine part—the first transfer of product data between different systems with the draft international standard. Ford engineers estimate that STEP will ultimately cut powertrain design and manufacturing costs by about 25 percent.

STEP has also been involved in the making of machined parts for the military in several U.S. facilities that use a system called rapid acquisition of manufactured parts (Ramp). Ramp was developed by Grumman Data Systems Corp., Bethpage, N.Y., and other companies participating in the South Carolina Research Authority's Computer Integrated Manufacturing team. Grumman reports that Ramp cuts the time needed to manufacture the parts, often not produced on a regular basis, by about 90 percent—from 300 to about 30 days.

Software for the design and manufacture of printed-circuit boards underwent a number of developments. ATTDFA, design for assembly software first developed by AT&T

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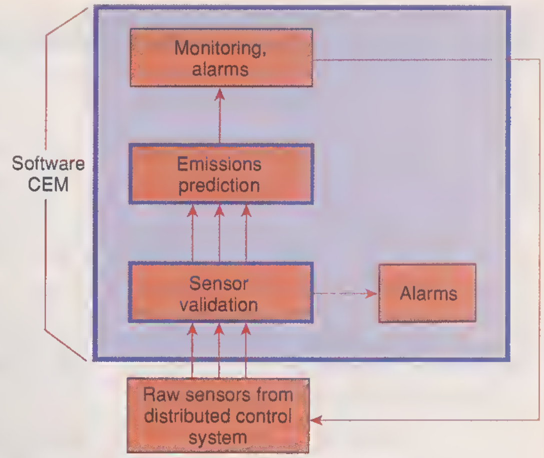
Bell Laboratories, Holmdel, N.J., for its own use, will soon be available from AT&T Design Automation, Holmdel, N.J., according to Anne Gitlow, a consultant to the company. Among other features, ATTDFA calls the user's attention to design rule violations—the creation of undesirable solder mask slivers, for instance—thereby preventing potentially costly manufacturing errors.

ATTDFA is the first of a series of software packages, planned for release this year and next, that will make up the company's ATTDFM Station. This comprehensive design for manufacturing package will comprise ATTDFF, a design for fabrication system; ATTDFT, a design for test system; and ATTDFX, a design for analysis system. These, along with the company's new Design for Testability System with its comprehensive mixed signal simulation tool set, will make AT&T an important player in the design automation market.

Greater flexibility in the design of testing fixtures for printed-circuit boards is among the new features in Version 5 of FABmaster, a software tool for automating circuit board production from Fabmaster SA, Grenoble, France, a leading vendor of graphics software tools in this field. Another attractive feature is this version's support of not one nail type (as before) but up to 255 nail types for the bed-of-nails test fixture design. Fabmaster has also added a rework tool that simplifies adjusting a design to an engineering change order; the tool serves to cut undesirable copper links, to add jumper straps, and to add and remove parts.

MORE CONTROL POWER. On the manufacturing floor, programmable logic controllers (PLCs) have become more powerful. From Siemens Industrial Automation Inc., Alpharetta, Ga., for example, came the Simatic TI555 PLC, which offers high-performance sequential PID (proportional, integral, derivative) control and can also be programmed in such high-level languages as C. GE Fanuc Automation North America Inc., Charlottesville Va., came up with more powerful central processing units (CPUs) for its midrange programmable logic controllers, the Series 90-30, and its high-end PLC Series 90-70. The new Model 341 CPU for the Series 90-30 cut the time needed to scan 1000 Boolean instructions to 0.3 ms from 0.4 ms, and the execution times of most non-Boolean instructions have been halved. At the same time, the memory capacity for the new 90-30 rose to 40 000 words, from 8000, surpassing the storage facilities of many high-end PLCs.

GE Fanuc's Series 90-70 is the first of this type of controller to be based on the Intel 486 processor, the foundation for a new CPU—the Model 914. With 512 kilobytes of 32-bit user memory, the CPU is capable of outdoing many competing products, the company believes. The CPU's flash memory also makes the controller much easier to start up and to upgrade than previous models were; the flash memory permits the operating system to be downloaded and reprogrammed with a 90-mm floppy disk inserted into a programming unit, which is in turn connected to the CPU's serial port.



Neural-network–based software from Pavilion Technologies Inc., Austin, Texas, uses raw sensor data from a plant's distributed control system, as well as a model of the process, to predict plant emissions. (The package is called Software CEM, for Continuous Emissions Monitoring system.) The model, constructed from earlier plant data through nonlinear regression, is captured in the neural network. If the plant exceeds the allowed emissions level, the system issues an alarm. A sensor-validation module in the software, again based on the earlier plant data and model, ensures that all sensors are functional, reconstructs bad sensor values, and warns of faulty sensors.

More system integration and greater power go into Allen Bradley Co.'s PLC-5 programmable logic controllers through added communications capabilities—Ethernet TCP/IP (transmission control protocol/Internet protocol)—making these PLCs likely partners in open systems solutions.

GOING FUZZY. Fuzzy logic is at home in industrial-control applications. The C200H-FZ001 coprocessor board, for example, from Omron Electronics Inc., Schaumburg, Ill., plugs into a backplane of the company's C200H programmable logic controller; another Omron fuzzy logic product, the ES100, is a compact process controller. Siemens Components Inc., Santa Clara, Calif., a company owned by Siemens AG, Munich, Germany, offers a fuzzy coprocessor chip, the SAE 81C99. Omron's C200H-FZ001 coprocessor, a module developed for use with the company's programmable logic controllers, lets operators mix fuzzy and conventional control.

Siemens' SAE 81C99 coprocessor chip has a peak performance of 7.9 million rules per second at 20 MHz, which is faster than many competing products. The device gives users more freedom to select membership functions for fuzzy logic statements than other coprocessors on the market do; the functions are programmable in 8-bit space, and their shape is not restricted.

Omron's ES100 combines fuzzy logic with advanced PID control. According to a company spokesman, the controller is also unique in its use of fuzzy logic for adaptive tuning that alters PID constants in response to operator requests to stabilize the control, reduce overshoot, optimize the system's response time, and so forth. Not the least important aspect of the controller is its compactness: at about 110 by 100 by 180 mm, it is half as big as competing products with similar capabilities.

At Allen Bradley Co., Milwaukee, Wis. (a unit of Rockwell International Corp.), fuzzy logic controllers are designed as software subroutines. The software allows the company's programmable controllers to execute both the logic program and the fuzzy logic applications within the same processor.

As for fuzzy logic development tools, Togai InfraLogic Inc., Irvine, Calif., a leading fuzzy logic company, recently announced its TILShell 3.0, a tool that helps design, debug, and test fuzzy logic expert systems and then creates the output code needed to implement the system. An update of the company's earlier tool, TILShell 3.0 has several new features, including real-time, on-line debugging and tuning of fuzzy rules, membership functions, and rule weights— all vital elements in the design of fuzzy logic controllers. The update includes graphical object-based computer-aided software engineering tools.

Togai Infralogic is also developing a special version of TILShell for fuzzy logic-based software used with Hartmann & Braun's Contronic P industrial-control products. Hartmann & Braun AG, Frankfurt, Germany, is a member of the Mannesmann Group and a key player in instrumentation and process automation. A similar collaboration between Togai InfraLogic and Siemens AG's Corporate Research Laboratories, Munich, has already borne fruit in the form of fuzzy control for Siemens' Siwamat washing machine, which is marketed in Europe. In this case, fuzzy logic helps control the machines when they must cope with unbalanced loading, a tough problem because of their horizontal axis of rotation.

BATCH CONTROL ON THE FLY. In the field of process control, one notable new product is GE Fanuc's Cimplicity Batch Control System (BCS) for distributed batch control and data acquisition. The product is one of the company's latest additions to its growing Cimplicity computer-integrated manufacturing (CIM) systems.

Cimplicity BCS is significant because it permits users "to change setups on the fly without recoding and reprogramming," said Larry MacDonald, manager of GE Fanuc's Batch Control Program, Charlottesville, Va. The system, which complies with the Instrument Society of America's emerging SP88

batch standard, makes modeling processing plants, a critical activity, "much more user-friendly," said MacDonald; there is "no need [for] familiarity with a computer language," he added. Emphasizing open architecture, Cimplicity BCS is compatible with not only GE Fanuc's line of PLCs but also those from other vendors.

Elsewhere in the field of process control, neural networks are on the move, not least as a result of their ability to extract predictive models from multidimensional data, even when the data contain unknown nonlinear relationships. Neural networks are not only scoring big successes and saving large sums in operating costs, but they are also helping to reduce environmental pollution.

A notable success is the Software CEM (Continuous Emissions Monitoring) system from Pavilion Technologies Inc., Austin, Texas, a model-based software system that predicts process plant emissions from readings of the plant's sensors. According to the company, Software CEM permits users to comply with the emissions requirements of the 1990 U.S. Clean Air Act for about half to a third of what a hardware-based continuous-emission-monitoring system would cost. Last August, the Texas Air Control Board allowed process industries to replace hardware-based systems with predictive emission-monitoring systems similar to, or the same as, the one offered by Pavilion Technologies.

Other successful neural network applications improve process control. At a factory in Kitakyushu-shi, in Japan, Fujitsu Ltd., Kawasaki, and Nippon Steel Corp. developed a system that predicts breakouts in the continuous casting of steel. The Intelligent Arc Furnace, from Neural Applications Corp., Coralville, Iowa, is a software package that controls electrode positions in arc furnaces. NeuCOP, a multivariable control and optimization package from NeuralWare Inc., Pittsburgh, was recently installed at Texaco's Puget Sound plant, in Washington state, to control the company's distillation tower; the package follows the company's introduction of DANA (design advisor, neural analyzer) for process modeling. A partnership between Adaptive Solutions Inc., Beaverton, Ore., a company specializing in neural networks, and Meidensha Corp., Tokyo, will develop a speech recognition system to monitor and control large industrial equipment on a hands-off basis.

Meanwhile, power electronics systems for adjustable speed drives have increased their range to cover systems of up to about 750 kW, up from about 600 kW earlier, mostly due to thyristors that switch faster. As a result, the undesirable harmonics injected into utility systems by power electronics loads are getting more attention than ever before.

One outcome is "IEEE Standard 519-1992: Recommended practices and requirements for harmonic control in electric power systems," the latest revision available since last June. The standard will allow power utilities and users to cooperate in an effort to improve power quality for all.

Last but not least, work toward a universal field bus standard by the International Electrotechnical Commission is progressing at the Instrument Society of America SP-50 Committee. Two consortia have been established—WorldFIP, based on the factory information protocol (FIP), and the Interoperable Systems Project (ISP), based primarily on the Profibus, or process field bus, that originated in Germany. Both organizations have demonstrated technologies that support the emerging standard. ◆

STRUGER: Automation augurs the renaissance of manufacturing

VIEWPOINT

"The conversion of information into structured matter by means of controlled energy" is how modern manufacturing has been defined by Hans Jürgen Warnecke, professor of industrial manufacturing and management at the University of Stuttgart and head of the Fraunhofer Institute in Germany. Clearly, if he is right, progress in manufacturing will depend heavily on the application of information, automation, and control technologies.

Billions of dollars are spent worldwide on basic research each year, so technologies often become available long before industry is ready to adopt them. Only recently have such artificial intelligence techniques as rule-based inferencing become industrial-strength tools for manufacturing applications. Although fuzzy logic has been well understood for more than a decade, only in the past year did a number of industrial-control vendors make this technology generally available on their systems. Neural network technology for manufacturing is still on the back burner.

Nonetheless, the functional capabilities of industrial control equipment follow the hyperexponential trend observed in technology growth as a whole. For instance, a typical programmable controller system's functional capabilities grew by three orders of magnitude between 1970 and 1980. Moreover, the explosive growth of technology, the increasing globalization of both markets and manufacturing operations, the appearance of ever more sophisticated consumers, and growing demands for environmental protection have all combined to create pressures for revolutionary change in manufacturing practices.

The required transformation has been characterized as a paradigm shift to "agile" enterprises capable of producing semicustom products in small lots, at an economic and environmental cost no higher than that of today's mass production.

'What is needed is the integration of people and intelligent machines...in a way that improves the flexibility, the agility, and the quality of the whole manufacturing enterprise'

In the face of such monumental changes, manufacturing will become even more information-driven. Only enterprises that can bring into play the knowledge of all their employees, both white and blue collar, will survive. What is needed is the integration of people and intelligent machines within the entire range of corporate activities, and in a way that improves the flexibility, the agility, the productivity, and the quality of the whole manufacturing enterprise.

These issues are being addressed by a two-year international feasibility study in Intelligent Manufacturing Systems (IMS), currently in progress in Japan, the United States, the countries of the European Union (formerly Community) and of the European Free Trade Association (EFTA), Canada, and Australia. As part of this study, which is scheduled to be completed in March 1994, six international consortia are conducting test cases in collaborative international research and development.

Allen-Bradley Co., Milwaukee, Wis., currently serves as principal coordinating partner of one of these groups, the Holonic Manufacturing Systems Consortium, which is conducting a test case in research, precompetitive development, and the systematization and standardization of architecture and technology for open, distributed systems in which autonomous, cooperating elements (holons) encompass discrete, continuous, and batch processing.

People will clearly play a key role, for many years to come, in providing exactly the attributes essential for the manufacturing systems of the year 2000: autonomy, cooperation, and intelligence. If such efforts as the IMS program prove successful, the answer to the question "where will all the manufacturing workers go?" will be "back into manufacturing—as human beings rather than as automata!" But one thing is clear: there will be an ever-increasing demand for technical professionals and a decreasing need for blue-collar workers.

Odo J. Struger (F) is vice president, technology, of the Allen-Bradley Co., a wholly owned subsidiary of Rockwell International Corp., headquartered in Milwaukee, Wis. Struger has more than 35 years of experience in industrial-control and automation technology. He holds over 45 patents and is the author of over 30 books and articles in this area..

The specialties

Public transit systems using magnetic levitation may prove more attractive to cities considering building them thanks to new sliding-mode switching controls. Also becoming attractive are surface acoustic wave devices for consumer applications, particularly for mobile communication handsets. Short-wavelength semiconductor and gas lasers look promising for such fields as environmental remediation, materials processing, and data storage. But with the growing number of electronic information sources, communicators are discovering they must be versed in a wide assortment of software packages. These are among specialized branches of electrical engineering in which IEEE Societies have reported recent advances.

Computer-aided communication

While the previous year's concerns for those who work on engineering documents were multimedia and interactive documents, this past year "information sources seem to be an increasing problem," according to David L. McKown of the IEEE Professional Communication Society.

The communicator, in combining the electronic input from multiple authors and illustrators, must deal with text received on diskette, by e-mail, downloaded from mainframes, and sent in as facsimiles, printouts, or handwritten drafts. Figures may be prepared in any number of illustrator or spreadsheet programs with their own special fonts and tabular format. All these must be merged into one compatible whole.

The communicator can no longer be just a writer or editor, but now "has to know which files can be combined easily, and must be familiar with the dozens of work-arounds for incompatible file formats," McKown said, "tasks that used to belong in the realm of a systems administrator, programmer, or friendly office hacker." These tasks add to the time and cost of the final document or publication.

This problem might be solved by improving the interchangeability of file formats, especially those of graphics and integrated documents, McKown pointed out. "More work is needed on a truly hardware- and software-independent form of document," he said. Because such a solution is certain to be resource-hungry, also needed are larger, more affordable, and rugged data storage devices that are independent of platform.

SAW filters go consumer

A big advance in the field of ultrasonics has been the use of surface–acoustic-wave (SAW) filters in consumer products. SAW filters have three advantages: they are small, rugged, and stable, making them useful for several industries. Each year, more than 100 million SAW IF filters are being manufactured for television receivers. More and more are also being used for channel filtering as well as for RF filtering in mobile communication systems, according to Clemens C. W. Ruppel of Siemens Corporate Research and Development in Munich, Germany. Ruppel is a member of the technical program committee of the Ultrasonics, Ferroelectrics, and Frequency Control Society.

"The trend toward higher frequencies for remote control systems makes SAW resonators advantageous for the frequency-determining devices in these systems," Ruppel wrote in his review paper "SAW Devices for Consumer Communication Applications," published in the September 1993 issue of *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control.* "A new application for SAW filters might be analog correlators in mobile telephones using code division multiple access."

Controls give maglev an edge

Sliding-mode control is a form of switching control well suited to nonlinear systems. One application is maintaining the clearance of magnetically levitated vehicles above the tracks—under a wide range of operating conditions and sensor variations. In fact, according to Tim Johnson, vice president of technical affairs in the Control Systems Society, this approach increases the safety of maglev systems and reduces the cost of their tracks.

Also new are integrated human-machine interfaces, the name given to a new workstation technology that uses animated graphics. It improves the coordination of systems being operated at a distance (teleoperation systems) because they are in space or are handling nuclear or hazardous materials. Force-reflecting systems with two or more arms may be controlled by a person responding naturally to visual inputs.

Meanwhile, genetic search techniques—those that create many optional models and then select the solutions that best fit the data—have been used to better model the drivetrain of an automobile. Specifically, genetic algorithms have been used in combination with physical modeling to help in simulating the jerk felt when a vehicle's accelerator is applied in low gear. As the application of genetic algorithms is a general technique, it may be used in any field where mathematical models have many unknown parameters.

Spotlight on blue and UV lasers

Recently developed blue and blue-green light-emitting diodes (LEDs) and diode lasers have made several new applications possible, according to Russell D. Dupuis, chair of the Technical Committee on Materials and Processing. The materials being developed for blue emitters include the II-VI compounds zinc cadmium selenide (ZnCdSe) and zinc sulfur selenide (ZnSSe). Key here is the growth of p-type zinc selenide (ZnSe) by means of molecular-beam epitaxy; the ZnSe is then doped with nitrogen using a nitrogen RF plasma source that decomposes nitrogen from a molecular into an atomic state.

Another materials system that looks hopeful for ultraviolet and blue emission is aluminum indium gallium nitride (AlInGaN). As before, the key is the development of a p-type magnesium dopant.

Blue and ultraviolet-emitting LEDs have been reported, and an injection laser (a diode laser activated by the injection of current) is expected in the near future. "These materials advances provide the exciting possibility of a combined white-light semiconductor injection laser system for a variety of applications," Dupuis noted.

Also advancing are short-wavelength gas lasers, according to Ronald W. Waynant of the U.S. Food and Drug Administration in Rockville, Md. Last year researchers at Rice University in Houston, Texas, took a leap forward in developing excimer lasers by using the Cs2+F- laser, which emits at a wavelength of 185 nm.

The pumping mechanism was a laser-produced plasma source that photo-ionized the cesium fluoride vapor, a technology that might be extended to other ionic excimers with other wavelengths and perhaps with better output. Applications for shorter wavelengths include materials processing and semiconductor device lithography.

Other research is opening up new uses for ultraviolet lasers. Among them is the photodecomposition of pollutants in the environment and the remote determination of atmospheric ozone concentrations. ◆

Trudy E. Bell Senior Editor

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To probe further

MEDIA EVENT. Transcripts of the "Donahue" and "Nightline" broadcasts on virtual reality are available at US $3.00 each from Journal Graphics, 1535 Grant St., Denver, Colo.; 303-831-9000.

TELECOMMUNICATIONS. *The Geodesic Network II: 1993 Report on Competition in the Telephone Industry* by Peter W. Huber, Michael K. Kellogg, and John Thorne (The Geodesic Co., Washington, D.C., 1992) is a recent analysis of the state of the telephone industry.

"Personal Wireless" by Bennett Z. Kobb, *IEEE Spectrum,* June 1993, pp. 20–25, introduces the technical and regulatory issues affecting the development of personal communications services. George Calhoun examines these issues in detail in *Wireless Access and the Local Telephone Network* (Artech House, Boston, 1992).

DATA COMMUNICATIONS. *Gigabit Networks* by Craig Partridge (Addison-Wesley, Reading, Mass., 1994) describes Bolt, Beranek, and Newman's gigabit project.

Enterprise Networking: Fractional T1 to SONET, Frame-Relay to B-ISDN by Daniel Minoli (Artech House, Boston, 1993) is a detailed reference work on past, present, and future wide-area network technologies.

CONSUMER ELECTRONICS. Digital compression for television transmission and interactive TV is explained in *Twenty-First Century Television: Cable Television in the Information Age* (National Cable Television Association, Washington, D.C.); 202-775-3680.

Technical aspects of new consumer electronics developments will be discussed at the IEEE Consumer Electronics Society's 1994 International Conference on Consumer Electronics, June 21–23, Rosemont, Ill. Call Diane Williams at 716-392-3862 for information.

PCs AND WORKSTATIONS. *Client/Server Computing* by Dawna Travis Dewire (McGraw-Hill, New York, 1993) gives a detailed overview of current system architectural and operating system issues. The April 1993 issue of *American Programmer* (Cutter Information Corp., Arlington, Mass.) has a quick overview of the same issues from a programmer's point of view.

Helen Custer's *Inside NT* (Microsoft Press, Redmond, Wash., 1993) is an authoritative book on Windows NT.

SOFTWARE ENGINEERING. Paul E. Renaud surveys marketing and technical considerations of client-server computing applications in *Introduction to Client/Server Systems* (John Wiley & Sons, New York, 1993).

Object Oriented Modeling and Design by Jim Rumbaugh and others (Prentice Hall, Englewood Cliffs, N.J., 1991) is a bible for methods of object-oriented programming.

APPLICATION SOFTWARE. *Networking Windows NT* by John D. Ruley and colleagues (John Wiley & Sons, New York, 1993) is a description of the Windows NT operating system and its networking capabilities. Simon Barry's "It's not just for mainframes anymore: symbolic math software," which starts on p. 405 of *PC Magazine*'s August 1992 issue, gives an overview of five symbolic math software packages.

LARGE COMPUTERS. The chief forum for discussing technical advances in high-end computing is the *Proceedings of the Supercomputing '93 Conference*, sponsored by the IEEE Computer Society and held in Portland, Ore., Nov. 15–19. It is available as Catalogue No. 93CH3342-3; call 202-371-1013.

In *High-Performance Computing: Advanced Research Projects Agency Should Do More to Foster Program Goals* (May 1993), the U.S. General Accounting Office notes that improvements are needed before the systems can play a larger role in commercial applications.

SOLID STATE. A textbook by Daniel Tabak, *Advanced Microprocessors* (McGraw-Hill, New York, 1991), describes the architectures and organization of many devices. *Microprocessor Report*, a newsletter published 17 times a year by MicroDesign Resources, Sebastopol, Calif. (707-824-4004), keeps readers up to date on recent developments in integrated circuit designs.

The June 1993 issue of the IEEE Computer Society's bimonthly magazine, *IEEE Micro*, has informative articles on Intel's Pentium, Hewlett-Packard's PA7100, and DEC's Alpha 21064 microprocessors.

POWER AND ENERGY. The *Electricity Journal*, a monthly published in Seattle, Wash., provides commentary and in-depth reports on critical issues in the utility industry. Call 206-448-4078 for more information. *IEEE Power Engineering Review*, published by the Power Engineering Society, has articles of a technical nature, as well as Society news.

TEST AND MEASUREMENT. For an overview of IEEE/ANSI Std 1149.1, including a discussion of its significance and a description of its most important features, see "Testability on TAP," by Colin M. Maunder and Rodham E. Tulloss, *Spectrum*, February 1992, pp. 34–37. A complete description of Maunder's proposal for managed built-in test is available in his paper "A Universal Framework for Managed Built-In Test," *Proceedings, International Test Conference 1993*, pp. 21–29.

TRANSPORTATION. The cover story of the October 1993 issue of *Mechanical Engineering* features American Flywheel's design and plans. Alex Taylor argues against meeting zero emission standards with electric cars in the July 26, 1993, issue of *Fortune*, while Victor Wouk and Illy Sobel debate the merits of the hybrid electric vehicle in the December 1993 issue of *Spectrum*.

Congressional Quarterly Researcher, April 16, 1993, examines magnetic levitation and high-speed rail issues.

AEROSPACE AND MILITARY. The difficulties of the Hubble Space Telescope and plans to repair it are detailed by Richard Tresch Feinberg in "Hubble's Road to Recovery," and by astronaut Jeffrey Hoffman in "How We'll Fix the Hubble Space Telescope," both in *Sky & Telescope*, November 1993, pp. 16–19; see also the April 1993 issue.

MEDICAL ELECTRONICS. Maurice Freedman discusses the European standards situation in "The EC Medical Devices Directives," *IEEE Engineering in Medicine and Biology*, June 1993.

IEEE Visualization '93, held Oct. 25–29, included sessions on medical simulation. For information, contact the IEEE Customer Service Center; 800-678-IEEE.

INDUSTRIAL ELECTRONICS. Neural networks are discussed in "Neural networks at work," *Spectrum*, June 1993, pp. 26–32, and in "Working with neural networks," *Spectrum*, July 1993, pp. 46–53. "Neural networks: applications in industry, business and science," *Communications of the ACM*, Vol. 37, no. 3, to be published in March 1994, deals with applications.

The September 1993 issue of *Spectrum* is devoted to new technologies in manufacturing. For the English version of DIN 19 245, the international standard for the Profibus fieldbus, contact Profibus Trade Organization, 750 Holiday Dr., Building 9, Pittsburgh, PA 15220; 1-800-228-1737 or 412-921-3322; fax, 412-921-3356.

Acknowledgments

This issue would not have been possible without the help of many experts in the IEEE technical societies who generously submitted material, and the many technical reviewers we called upon to critique the material planned for the issue before it was released to publication.

The pictures of the experts that appear with each major article in this issue were drawn by Barry Ross, Northampton, Mass.

1994 IEEE guide for authors

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In the listings below, frequency of publication is noted in parentheses.

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George Watson, Proceedings of the IEEE, 445 Hoes Lane, Piscataway, NJ 08855 908-562-5478

IEEE TRANSACTIONS, JOURNALS, AND MAGAZINES

These publications of IEEE Societies provide the means by which the member keeps abreast of the advances in specific fields. Their mission is to record and disseminate new scientific and technical information for present and future members of the profession.

Aerospace and Electronic Systems, IEEE Trans
Equipment, procedures, and techniques applicable to the organization, installation, and operation of functional systems meeting high-performance requirements of earth and space systems. (4)
Jack R. Harris, 20400 Highland Hall Dr., Gaithersburg, MD 20879 301-251-4810

Aerospace and Electronic Systems Magazine
Aspects of earth and space systems, radar, navigation, guidance and control, and communication data handling as well as systems for their simulation and test. Intended to keep engineers current in development, operation, and test of civil and military electronic systems. (12)
H. Warren Cooper, 7211 Windsor Lane, Hyattsville, MD 20782 301-927-7681

Annals of the History of Computing
Chronicles vital contributions and their impact on society. Departments: Happenings; Biographies; Anecdotes; Self-Study Q&A; Reviews; and Comments, Queries, and Debate. (4)
J.A.N. Lee, V.A. Tech., 133 McBride Hall, Blacksburg, VA 24061 703-231-6705

Antennas and Propagation, IEEE Trans.
Experimental and theoretical advances in electromagnetic theory and in the radiation, propagation, scattering and diffraction of electromagnetic waves, and the devices, media and fields of application pertinent thereto such as antennas, plasmas, and radio astronomy systems. (12)
Ronald J. Marhefka, Electroscience Labs, Ohio State University, 1320 Kinnear Rd., Columbus, OH 43212-1191

Antennas and Propagation Magazine
Antenna theory, design and practice; propagation, theory and effects; and a broad range of general interest topics including basic electromagnetics, computational and numerical techniques, personal computers for EEs, scattering and diffraction, radar and radar cross sections. (6)
W. Ross Stone, Expersoft Corp., 1446 Vista Claridad, La Jolla, CA 92037 619-459-8305

Applied Superconductivity, IEEE Trans.
Contains articles on the applications of superconductivity and relevant technology. Electronic applications include analog and digital circuits employing thin films and active devices such as Josephson junctions. Power applications include magnet design as well as motors, generators, and power transmission. (4)
Theodore Van Duzer, Dept. of EECS, University of California, Berkeley, CA 94720
415-642-3306

Automatic Control, IEEE Trans.
The theory, design, and application of control systems: real-time control, optimal control, adaptive and stochastic control, estimation and identification, linear systems, system modeling, and applications of physical, economic and social systems. (12)
John Baillieul, Department of Aerospace/Mechanical Engineering, Boston University, 110 Cummington St., Boston, MA 02215
617-353-9848

Biomedical Engineering, IEEE Trans.
Broad coverage of concepts and methods of the physical and engineering sciences applied in biology and medicine, ranging from formalized mathematical theory through experimental science and technological development to practical clinical applications. (12)
Dr. Michael R. Neuman, Obstetrics & Gynecology, MetroHealth Medical Center, 2500 MetroHealth Dr., Cleveland, OH 44109
216-459-5095

Broadcasting, IEEE Trans.
Broadcast technology, including the production, distribution, transmission, and propagation aspects of broadcasting. (4)
Phil Rubin, Rubin, Bednarek & Associates, 1350 Connecticut Ave., Suite 610, Washington, DC 20036 202-296-9380

Circuits and Devices Magazine
Provides in-depth assessments of emerging technologies and their continued impact on the human-machine interface. Included are papers and

tutorials on VLSI; manufacturing technology; semiconductor processes; quantum electronics; digital and analog circuits; components and packaging. Also, book reviews, news and notes, conferences, workshops, seminars, and lectures. (6)
Ronald W. Waynant, Food and Drug Administration, Center for Devices and Radiological Health (CDRD), Electro-Optics Branch, HFZ-134, Rm 12, 1901 Chapman Rd., Rockville, MD 20857 301-443-2965

Circuits and Systems, Part I: Fundamental Theory and Applications; IEEE Trans.
Widely recognized forum for new results in electronic circuits and systems; system theory; discrete, IC, and VLSI circuit design; nonlinear circuits and systems; multidimensional circuits and systems; theory of analog and discrete-time filtering; graph theory; and large-scale systems and power networks. (12)
Martin Hasler, Department of Electrical Engineering, Ecole Polytechnique Federale de Lausanne, EPFL-Ecublens CH-1015 Lausanne, Switzerland

Circuits and Systems, Part II: Analog and Digital Signal Processing; IEEE Trans.
Analog and digital signal processing, including active, passive, switched-capacitor, and digital filters; nonlinear filters and signal-processing operators; new hardware structures and software algorithms for signal processing; video and image processing; and signal processing in higher dimensions. (12)
David Allstot, Dept. of Electr. and Computer Eng., Carnegie Mellon University, Pittsburgh, PA 15213

Circuits and Systems tor Video Technology, IEEE Trans.
Video A/D and D/A, display technology, image analysis and processing, video signal characterization and representation, video compression techniques and signal processing, multidimensional filters and transforms, analog video signal processing, neural networks for video applications, nonlinear video signal processing, video storage and retrieval, computer vision, packet video, high-speed real-time circuits, VLSI architecture and implementation for video technology, multiprocessor systems—hardware and software—video systems architecture, video quality assessment, and other video-technology-related topics. (6)
Ming Liou, Hong Kong University Science and Technology, Dept. of EE Eng., Clear Water Bay, Kowloon, Hong Kong

Communications, IEEE Trans.
Telephone, telegraphy, facsimile, and point-to-point television, by electromagnetic propagation, including radio; wire; aerial, underground, coaxial, and submarine cables; waveguides, communication satellites, and lasers; in marine, aeronautical, space and fixed station services; repeaters, radio relaying, signal storage, and regeneration; telecommunication error detection and correction; multiplexing and carrier techniques; communication switching systems; data communications; and communication theory. In addition to the above, this Transactions contains papers pertaining to analog and digital signal processing and modulation, audio and video encoding techniques, the theory and design of transmitters, receivers, and repeaters for communications via optical and sonic media, the design and analysis of computer communication systems, and the development of communication software. (12)
Joseph LoCicero, Dept. of EE, Illinois Institute of Technology, Chicago, IL 60616
312-567-3408

Communications Magazine
All areas of communications: conferences, short courses, standards, governmental regulations and legislation, book reviews, and special feature technical articles; Society news, including administration and elections. (12)
Tom Plevyak, Bell Atlantic, 1310 N. Court House Rd., 3rd Floor, Arlington, VA 22201
703-974-5655

Communications, Selected Areas in; IEEE J.
All telecommunications, including telephone, telegraphy, facsimile, and point-to-point television, by electromagnetic propagation, including radio; wire; aerial, underground, coaxial, and submarine cables; waveguides, communication satellites, and lasers; in marine, aeronautical, space, and fixed station services; repeaters, radio relaying, signal storage, and regeneration; telecommunication error detection and correction; multiplexing and carrier techniques; communication switching systems; data communications; and communication theory. (9)
William H. Tranter, Dept. of EE, University of Missouri, Rolla, MO 65401 314-341-4514

Components, Packaging, and Manutacturing Technology, Part A: IEEE Trans.
Component parts, hybrid microelectronics, materials, packaging techniques, and manufacturing technology. (4)
Paul G. Slade, Westinghouse Science & Tech. Ctr, Westinghouse Circle, Horseheads, NY 14845
607-796-3230

Components, Packaging, and Manutacturing Technology, Part B: Advanced Packaging, IEEE Trans. (4)
Che Yu Li, Bard Hall, Cornell University, Ithaca, NY 14853 607-255-4349

Computational Science and Engineering
Articles defining the field as the interface among the applications (in science and engineering), algorithms (numerical and symbolic), system software, and computer architecture. Articles should be readable by specialists from various disciplines; i.e. should overcome the barriers usually created by discipline-oriented vocabularies. Articles describing future workbenches for developing application software in various disciplines will be encouraged. (4)
Ahmed Sameh, Computer Science Dept., Univ. of Minnesota, 4-192 EE/CS Bldg., 200 Union St. SE, Minneapolis, MN 55455

Computer-Aided Design ot Integrated Circuits and Systems, IEEE Trans.
Methods, algorithms, and human-machine interfaces for physical and logical design, including: planning, synthesis, partitioning, modeling, simulation, layout, verification, testing, and documentation of integrated-circuit and systems designs of all complexities. Practical applications of aids resulting in producible analog, digital, optical, or microwave integrated circuits are emphasized. (12)
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Computer Applications in Power Magazine
Magazine devoted to computer applications to the design, operation, and control of power systems. Includes articles on transient network analysis, circuit evaluation, steady-state analysis, cable management systems, economics, and contingency analysis. (4)
William R. Brownlee, 350 Galleria Woods Dr., Birmingham, AL 35244 205-985-7530

Computer Graphics and Applications Magazine
Computer graphics hardware and software, display technology, computational geometry, geometric data structures and databases, industrial applications, animation methodology, human factors for graphics, interactive graphics languages, graphic arts, graphics support of MIS, and distributed graphics techniques. (6)
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Computer Magazine
Survey and tutorial articles covering computer hardware, software, and system design and application; special issues focus on such topics as VLSI design, software engineering, local area networks, computer communications, and computer architecture. Regular departments present new product announcements, book reviews, and professional calendar. (12)
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Computers, IEEE Trans.
Design and analysis of algorithms, computer systems, and digital networks; methods for specifying, measuring, and modeling the performance of computers and computer systems; design of computer components, such as arithmetic units, data storage devices, and interface devices; design of reliable and testable digital devices and systems; computer networks and distributed computer systems; new computer organizations and architectures; applications of VLSI technology to computers; human factors and interactive computer systems; application of computer technology to other disciplines such as automatic control, robotics, communication or real-time information processing, and instrumentation. (12)
Earl Swartzlander, Dept. ECE, University of Texas, Austin, TX 78712 512-471-5923

Consumer Electronics, IEEE Trans.
The design and manufacture of consumer electronics products, components, and related activities, particularly those used for entertainment, leisure, and educational purposes. (4)
Wayne C. Luplow, Zenith Electronics Corp., 1000 Milwaukee Ave., Glenview, IL 60025
312-391-7873

Control Systems Magazine
Control system applications and experiences, design tools, conference programs, educational features, book reviews, and Society news items. For practicing control system engineers. (6)
Stephen Yurkovich, Ohio State University, Dept. of EE, 408 Dreese Lab, 2015 Neil Ave., Columbus, OH 43210-1272 614-292-2586

Control Systems Technology, Trans.
An archival journal bridging theory and practice and covering advances in control engineering. Control systems from analysis and design through simulation and hardware. (4)
Bruce Krogh, Dept. ECE, Carnegie Mellon University, Pittsburgh, PA 15213
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Design and Test of Computers Magazine
Methods, practical experience, research ideas, and

commercial products that aid in the design and test of chips, assemblies, and systems —e.g., design automation, CAD workstations, design software, computer-aided test, test equipment, self-test, and design for testability. (4)
Manuel A. d'Abreau, Intel Corp., M/S FM 3108, 1900 Prairie City Rd., Folsom, CA 95630

Dielectrics and Electrical Insulation, IEEE Trans.
Electrical insulation common to the design and construction of components and equipment for use in electric and electronic circuits and distribution systems at all frequencies. (6)
Arend van Roggen, RD 2, Kennett Square, PA 19348 215-388-6909

Education, IEEE Trans.
Educational methods, technology, and programs; history of technology; impact of evolving research on education. (4)
Prof. Frank Barnes, Dept. of Electr. Eng., University of Colorado, Campus Box 425, Boulder, CO 80309-0425 303-492-5071

Electrical Insulation Magazine
Compilation of articles and news that relate to insulation and dielectrics. Includes conference activities reporting and papers of general interest. (6)
Frank Barnes, Univ. of Colorado, Dept. of EE, Campus Box 425, Boulder, CO 80309 303-492-5071

Electromagnetic Compatibility, IEEE Trans.
EMC standards; measurement technology; undesired sources; cable/grounding; filters/shielding; equipment EMC; systems EMC; antennas and propagation; spectrum utilization; electromagnetic pulses; lightning; radiation hazards; and Walsh functions. (4)
Motohisa Kanda, Electromagnetic Fields Division, National Bureau of Standards, Boulder, CO 80303 303-497-5320

Electron Device Letters
Theory, design, and performance of electron and ion devices, solid-state devices, integrated electronic devices, optoelectronic devices, and energy sources. Publication is two months from the end of the month in which manuscript is received. (12)
John Brews, Dept. of Electrical and Computer Engineering, Room 230, Building 104, University of Arizona, Tucson, AZ 85721 602-621-8734

Electron Devices, IEEE Trans.
The theory, design, and performance of active electron and ion devices, solid-state devices, integrated electron devices, and energy sources. (12)
Renuka Jindal, AT&T Bell Labs, Rt. 569 Carter Rd., PO Box 900, Princeton, NJ 08542 908-665-4235

Electronic Materials, IEEE J.
Applications of semiconductors, magnetic alloys, insulators, and optical and display materials. (12)
Theodore C. Harman, MIT Lincoln Laboratory, Lexington, MA 02173 617-981-4418

Energy Conversion, IEEE Trans.
Research, development, design, application, construction, installation, and operation of electric power generating facilities (along with their conventional, nuclear, or renewable sources) for the safe, reliable, and economic generation of electrical energy for general industrial, commercial, public, and domestic consumption. (4)
Harold Gold, 1037 North Primrose, Rialto, CA 92376; 714-875-8117. For information on manuscript submission: Nancy Heitmann, Society Special Services of Technical Activities Dept., IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331 908-562-3881

Engineering Management, IEEE Trans.
Management of technical functions such as research, development, and engineering in industry, government, university, and other settings. Emphasis is on studies carried on within an organization to help in decision making or policy formation for RD&E. (4)
Dundar F. Kocaoglu, Engineering Management Program, School of Engineering and Applied Science, Portland State University, Portland, OR 97207-0751 503-725-4660

Engineering Management Review
A reprint of selected papers relevant to engineering management. (4)
David S. Lewis, Box 18438, Irvine, CA 92713 714-633-9660

Engineering in Medicine and Biology Magazine
Contains general and technical short articles on current technologies and methods used in Biomedical and Clinical Engineering. Current news items, book reviews, patent descriptions, and a correspondence section are included. (4)
A.S. Wald, Dept. of Anesthesiology, Columbia-Presbyterian Medical Center, 630 W. 168th St., New York, NY 10032 212-305-2164

Expert Magazine (Intelligent Systems and Their Applications)
Tutorial and survey articles on the current applications of intelligent systems, including databases, expert systems, and artificial intelligence. (6)
B. Chandrasekaran, Ohio State University, Computer and Information Sciences Dept., Room 228, Bolz Hall, 2036 Neil Ave., Columbus, OH 43210-1277

Fuzzy Systems, IEEE Trans.
Theory and application of fuzzy systems with emphasis on engineering systems and scientific applications. (4)
James C. Bezdek, Dept. of Computer Sci., Univ. West Florida, Pensacola, FL 32514 904-474-2784

Geoscience and Remote Sensing, IEEE Trans
Theory, concepts, and techniques of science and engineering as applied to sensing the earth, oceans, atmosphere, and space; and the processing, interpretation, and dissemination of this information. (6)
James A. Smith, Terrestrial Physics Laboratory, Code 920, National Aeronautics and Space Administration/Goddard Center, Greenbelt, MD 20771 301-286-4950

Image Processing, IEEE Trans.
Signal-processing aspects of image processing, imaging systems, and image scanning, display, and printing. Includes theory, algorithms, and architectures for image coding, filtering, enhancement, restoration, segmentation, and motion estimation; image formation in tomography, radar, sonar, geophysics, astronomy, microscopy, and crystallography; image scanning, digital half-toning and display, and color reproduction. (4)
David C. Munson, Coordinated Science Laboratory, Univ. of Illinois, 1101 W. Springfield Ave., Urbana, IL 61801 217-333-4789

Industrial Electronics, IEEE Trans.
Theory and applications of industrial electronics and control instrumentation science and engineering, including microprocessor control systems, high-power controls, process control, programmable controllers, numerical and program control systems, flow meters, and identification systems. (6)
James C. Hung, Dept. of Electrical and Computer Engineering, 401 Ferris Hall, University of Tennessee, Knoxville, TN 37996 615-974-5420

Industry Applications, IEEE Trans.
The development and application of electric systems, apparatus, devices, and controls to the processes and equipment of industry and commerce; the promotion of safe, reliable, and economic installations; the encouragement of energy conservation; the creation of voluntary engineering standards and recommended practices. (6)
Edward A.E. Rich, 243 Juniper Dr., Schenectady, NY 12306 518-372-9572

Information Theory, IEEE Trans.
The fundamental nature of the communication process; transmission and utilization of information; coding and decoding of digital and analog communication transmissions; study of random interference and information-bearing signals; and the development of information-theoretic techniques in diverse areas, including communication systems, detection systems, pattern recognition, learning, and automata. (6)
Richard Blahut, IBM Corp., Bodle Hill Rd., Owego, NY 13827

Instrumentation and Measurement, IEEE Trans.
Measurements and instrumentation utilizing electrical and electronic techniques. (6)
Stephen A. Dyer, Kansas State University, 262 Durland Hall, Manhattan, KS 66506 913-532-5600

Knowledge and Data Engineering, IEEE Trans.
Artificial intelligence techniques, including speech, voice, graphics, images, and documents; knowledge and data engineering tools and techniques; parallel and distributed processing; real-time distributed processing; system architectures, integration, and modeling; database design, modeling, and management; query design, and implementation languages; distributed database control; statistical databases; algorithms for data and knowledge management; performance evaluation of algorithms and systems; data communications aspects; system applications and experience; knowledge-based and expert systems; and integrity, security, and fault tolerance. (6)
Benjamin Wah, Univ. of Illinois, C&SRL, 1308 West Springfield Ave., Urbana, IL 61801 217-333-3516

Lightwave Technology, J.
All aspects of optical guided-wave science, technology, and engineering in the areas of fiber and cable technologies; active and passive guided-wave componentry (light sources, detectors, repeaters, switches, fiber sensors, etc.); integrated optics and optoelectronics; systems and subsystems; new applications; and unique field trials. (12)
Donald Keck, Corning Glass Works, SP FR 29, Corning, NY 14831 607-974-3095

Magnetics, IEEE Trans.
Science and technology related to the basic physics of magnetism, magnetic materials, applied magnetics, magnetic devices, and basic and applied superconductivity. (6)
William Lord, College of Engineering, 104

Marston Hall, Iowa State University, Ames, IA 50011 515-294-3685

Medical Imaging, IEEE Trans.
Imaging of body organs, usually in situ, rather than microscopic biological entities; the associated equipment and techniques, such as instrumentation systems, transducers, computing hardware, and software. (4)
Gabor Herman, Hospital of Univ. Pennsylvania, Dept. Radiology, 3400 Spruce St., Philadelphia, PA 19104 215-662-6780

Micro Magazine
Microprocessor technology; computer-aided design; system support software, interfacing techniques, chip design, and fabrication; personal computing; control hierarchies, architectures, applications and draft standards for hardware, software, and interconnections. (6)
Dante Del Corso, Politecnico di Torino, Dipart. di Electr., Cso Duca degli Abruzzi, 24, Torino 10129, Italia

Microelectromechanical Systems, IEEE J.
Micromechanics, Microdynamics, Microelectromechanical Systems, MEMS: articles on small devices—from microns to millimeters; microfabrication techniques; microphenomena; microrobots; microbatteries, microbearings; and other microcomponents; theoretical, computational, modeling and control results; new materials and designs; tribology; microtelemanipulation; and applications such as biomedical engineering, optics, and fluidics. (4)
William Trimmer, Belle Mead Research Inc., 58 Riverview Terrace, Belle Mead, NJ 08502 908-359-0012

Microwave and Guided Wave Letters, IEEE
Published monthly with the purpose of providing fast publication of original and significant contributions relevant to all aspects of microwave/millimeter-wave technology. Emphasis is on devices, components, circuits, guided-wave structures, systems and applications covering the frequency spectrum from microwave and beyond, including submillimeter-waves and infrared. Publication time will be two months from the end of the month in which a contribution was received, provided the author responds immediately to all communications. Acknowledgment letters will not be sent to the authors. Galley proofs will be sent, but in the interest of fast publication, there may not be time to wait for their return. Errata will be published in the next issue if sent promptly. Lengths of the letters are expected to be no longer than two printed pages. (12)
Tatsuo Itoh, Dept. of Electrical and Computer Engineering, University of California, 66-147 A Engineering IV, 405 Hilgard Ave., Los Angeles, CA 90024 213-206-4820

Microwave Theory and Techniques, IEEE Trans.
Microwave theory, techniques, and applications as they relate to components, devices, circuits, and systems involving the generation, transmission, and detection of microwaves. (12)
Daniel Masse, 8 Puritan Place, East Walpole, MA 02302 508-660-2490

Multimedia
Research and advanced practice in hardware/software from theory to working systems. Aspects of special needs of multimedia information compared to other electronic data, e.g. the size requirements of digital media, and the importance of time in the representation of such media. (4)
Ramesh Jain, Dept. of ECE, Univ. of California at San Diego, La Jolla, CA 92093

Network Magazine (The Magazine of Computer Communications)
Network protocols and architecture; protocol design and validation; communications software; network control, signaling, and management; network implementation (LAN, MAN, WAN); and micro-to-host communications. (6)
Craig Partridge, 824 Kipling St., Palo Alto, CA 94301 413-326-4541

Networking IEEE/ACM Trans.
Network architecture and design, communication protocols, network software, network technologies, network software, network technologies, network services and applications, and network operations and management. (6)
James Kurose, Dept. Comp. & Info Sciences, Univ. Massachusetts, Amherst, MA 01003 413-545-1585

Neural Networks, IEEE Trans.
The theory, design, and application of neural networks, ranging from software to hardware. Emphasis will be given to artificial neural networks. Readers are encouraged to submit manuscripts that disclose significant technical achievements, indicate exploratory developments, or present significant applications for neural networks. This Transactions contains a Letters section intended to serve as a vehicle for rapid publication of new, significant, and timely research results. The Letters section also includes information of current interest, and comments and rebuttals in connection with published papers. (6)
Robert Marks, Dept. of Electrical Engineering, University of Washington, 1131 199th St. SW, Suite N, Seattle, WA 98195 206-543-6990

Nuclear Science, IEEE Trans.
All aspects of the theory and applications of nuclear science and engineering, including instrumentation for the detection and measurement of ionizing radiation; particle accelerators and their controls; nuclear medicine and its application; effects of radiation on materials, components, and systems; reactor instrumentation and controls; and measurement of radiation in space. (6)
Paul Dressendorfer, Sandia National Laboratories, Dept. 2277, Box 5800, Albuquerque, NM 87185 505-844-5373

Oceanic Engineering, IEEE J.
Bayes procedures; buried-object detection; dielectric measurements; Doppler measurements; geomagnetism; sea floor; sea ice; sea measurements; sea surface electromagnetic scattering; seismology; sonar; acoustic tomography; underwater acoustics; and underwater radio communication. (4)
William Carey, 79 Whipporwill Dr., Old Lyme, CT 06371 203-434-6394

Parallel and Distributed Systems, IEEE Trans.
Architectures—design, analysis, and implementation of multiprocessor systems (including multiprocessors, multicomputers, and networks); impact of VLSI on system design; interprocessor communications. Software—parallel languages and compilers; scheduling and task partitioning; databases, operating systems, and programming environments for multiple-processor systems. Algorithms and applications—models of computation; analysis and design of parallel/distributed algorithms; application studies resulting in better multiple-processor systems. Other issues—performance measurements, evaluation, modeling and simulation of multiple-processor systems; real-time, reliability and fault-tolerance issues; and conversion of software from sequential to parallel forms. (12)
Tse-Yun Feng, Dept. of ECE, 121 Engineering East Building, Pennsylvania State University, University Park, PA 16802 814-863-1469

Parallel and Distributed Technology Magazine
Advances in parallel and distributed computing technology, specifics on unique features and applications. Computational models, distributed databases, high-speed networks, numerical algorithms, parallel and distributed computer architectures, and supercomputing. (4)
Michael Quinn, Oregon State Univ., Dept. of Computer Sci., Corvallis, OR 97331 503-737-5572

Pattern Analysis and Machine Intelligence, IEEE Trans.
Statistical and structural pattern recognition; image analysis; computational models of vision; computer vision systems; enhancement, restoration, segmentation, feature extraction, shape and texture analysis; applications of pattern analysis in medicine, industry, government, and the arts and sciences; artificial intelligence, knowledge representation, logical and probabilistic inference, learning, speech recognition, character and text recognition, syntactic and semantic processing, understanding natural language, expert systems, and specialized architectures for such processing. (12)
Anil Jain, Dept. of Computer Science, A-726 Wells Hall, Michigan State University, East Lansing, MI 48824 517-353-5150

Personal Communications
Technical and policy issues relating to personalized, location-independent communications in all media and combination of media. Wired and wireless communications, focusing on the mobility of people, communicating devices, and personal services. (4)
Hamid Ahmadi, IBM TJ Watson Research Cntr., PO Box 704, Yorktown Heights, NY 10598

Photonics Technology, IEEE Letters
Rapid publication of original research relevant to photonics technology. This expanding field emphasizes laser and electro-optic technology, laser physics and systems, applications, and photonic/lightwave components and applications. The journal offers short, archival publication with minimal delay. (12)
Paul W. Shumate, Bellcore 2Q-186, 445 South St., Morristown, NJ 07960 201-829-4600

Plasma Science, IEEE Trans.
Plasma science and engineering, including: magnetofluid dynamics and thermionics; plasma dynamics; gaseous electronics and arc technology; controlled thermonuclear fusion; electron, ion, and plasma sources; space plasmas; high-current relativistic electron beams; laser-plasma interactions; diagnostics; plasma chemistry and colloidal and solid-state plasmas. (6)
Steven J. Gitomer, Group IT, Mail Stop B228, Los Alamos National Laboratory, PL Box 1663, Los Alamos, NM 87545 505-667-6922

Power Delivery, IEEE Trans.
Research, development, design, application, construction, the installation and operation of apparatus, equipment, structures, materials, and systems for the safe, reliable, and economic de-

livery and control of electric energy for general industrial, commercial, public, and domestic consumption. (4)

Harold Gold, 1037 North Primrose, Rialto, CA 92376 909-875-8117 For information on manuscript submission: Nancy Heitmann, Society Special Services of Technical Activities Dept., IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331 908-562-3881

Power Electronics, IEEE Trans.
Fundamental technologies used in the control and conversion of electric power. Topics include dc-to-dc converter design, direct off-line switching power supplies, inverters, controlled rectifiers, control techniques, modeling, analysis and simulation techniques, the application of power circuit components (power semiconductors, magnetics, capacitors), and thermal performance of electronic power systems. (4)

Richard Hoft, Electrical and Computer Engineering Dept., University of Missouri, 223 Electrical Engineering, Columbia, MO 65211 314-882-3491

Power Engineering Review
Electric power system engineering; includes one-page summaries of all papers accepted for publication in Energy Conversion, Power Delivery, and Power Systems. Also includes the Power Engineering Society Newsletter, selected prize papers, high-interest papers, and other articles of technical interest. (12)

C.J. Essel, 5969 W. 76th St., Los Angeles, CA 90045 310-645-3380

Power Systems, IEEE Trans.
Requirements, planning, analysis, reliability, operation, and economics of electrical generating, transmission, and distribution systems for industrial, commercial, public, and domestic consumption. (4)

Harold Gold, 1037 North Primrose, Rialto, CA 92376 909-875-8117 For information on manuscript submission: Nancy Heitmann, Society Special Services of Technical Activities Dept., IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331 908-562-3881

Professional Communication, IEEE Trans.
The study, development, improvement, and promotion of techniques for preparing, organizing for use, processing, editing, collecting, conserving, and disseminating any form of information in the electrical and electronics fields. (4)

Scott Sanders, Dept. of English Language and Literature, University of New Mexico, Albuquerque, NM 87131 505-277-4437

Quantum Electronics, IEEE J.
Generation, amplification, modulation, detection, waveguiding, or techniques and effects that can affect the propagation characteristics of coherent electromagnetic radiation having submillimeter and shorter wavelengths. (12)

Steven R.J. Brueck, Center for High Technology Materials, University of New Mexico, EECE Bldg., Rm. 125, Albuquerque, NM 87131 505 277-6033

Rehabilitation Engineering, IEEE Trans.
Rehabilitation aspects of biomedical engineering, including functional electrical stimulation, acoustic dynamics, human performance measurement and analysis, nerve stimulation, electromyography, motor control and stimulation, and hardware and software applications for rehabilitation engineering and assistive devices. (4)

Charles J. Robinson, Univ. Sch. Health & Rehabilitation, 107B Pennsylvania Hall, Univ. of Pittsburgh, Pittsburgh, PA 15216 412-624-8945

Reliability, IEEE Trans.
Principles and practices of reliability, maintainability, and product liability pertaining to electrical and electronic equipment. (4)

Dr. Michael Pecht, Mechanical Engineering Dept., University of Maryland, College Park, MD 20742 301-405-5278

Robotics and Automation, IEEE Trans.
Theory and applications in robot dynamics and control; simulation of robots and manufacturing systems; robot languages; robotic vision and other sensory interfaces; manipulator design; robot locomotion; management of multirobot systems; geometric modeling, other computer-aided design techniques; robot manufacturing; motion planning, task planning, and expert systems in robotics and automation; hardware and software implementation of robotic systems. (6)

Russell H. Taylor, Manufacturing Research Dept., IBM T.J. Watson Res. Center, Box 704, Yorktown Heights, N.Y. 10598 914-784-7796

Robotics and Automation Society Magazine
Applied research, state-of-the-shelf solutions and technologies, and education. Articles targeted towards the practicing engineer, emphasizing creative solutions to real-world problems, and highlighting implementation details. (4)

Michael Leahy, 1518 Saxonhill Dr., San Antonio, TX 78253

Semiconductor Manufacturing, IEEE Trans.
Process control techniques; process modeling, simulation, measurements, diagnostics; defect characterization and control; yield analysis and modeling; product design for manufacturability, reliability; product transfer from development to manufacturing; factory design, simulation; automation: models, algorithms, equipment interfaces, etc.; equipment design: modeling and simulation; production control and scheduling; operations management: training, incentives, productivity measures; standards: materials, processes; computer integration: computer-controlled equipment and facilities; and the application of AI and expert systems. (4)

Costas Spanos, 568 Cory Hall, University of California, Berkeley, CA 94720 510-643-6776

Signal Processing, IEEE Trans.
Transmission, recording, reproduction, processing, and measurement of speech and other signals by digital, electronic, electrical, acoustic, mechanical, and optical means; the components and systems to accomplish these and related aims; and the environmental, psychological, and physiological factors of these technologies. (12)

Pierce Wheeler, 435 Rt. 24, Chester, NJ 07930 908-879-5746

Signal Processing Letters
Rapid dissemination of new results in signal processing world-wide. (12)

Ahmed Tewfik, Dept. of Electr. Eng., Science Building, 200 Union St. SE, Univ. of Minnesota, Minneapolis, MN 55455 612-625-6024

Signal Processing Magazine
Acoustics, including digital audio, underwater signal processing, and electroacoustics; speech, including speech transmission and coding; enhancement and noise reduction; analysis and reconstruction; synthesis; recognition; production/synthesis; performance evaluation; signal processing, one-dimensional and multidimensional digital signal processing, including discrete Fourier and other transforms; nonlinear analysis; spectral analysis; signal and system identification; filter design and applications; applications to echo cancellation, aids for the handicapped, and radar; image processing; sensor array processing; multidimensional processing; VLSI; and hardware implementations. (4)

Gregory Wakefield, Univ. of Michigan, Dept. of EE&CS, Ann Arbor, MI 48109 313-763-9857

Software Engineering, IEEE Trans.
Specification, development, management, test, maintenance, and documentation of computer software. (12)

Nancy G. Leveson, Dept. Computer Science and Engineering, FR35, 314 Sieq Hall, Univ. of Washington, Seattle, WA 98195 206-685-1934

Software Magazine
Tutorials and surveys on current techniques and new products in software design and development. Focuses on such topics as software tools, measuring program reliability, designing software tests, PCs as programming workstations, localization of bugs, and making programs readable. (6)

Carl K. Chang, University of Illinois, Dept. EECS, M/C 154, 1120 Science and Eng. Offices, Chicago, IL 60680 312-996-4860

Solid-State Circuits, IEEE J.
Analysis, design, and performance of solid-state circuits; transistors; diodes; bulk-effect and magnetic devices; digital; analog; microwave; optoelectronic; integrated circuits; and large-scale integration. (12)

Asad A. Abidi, EE Dept., Room 56-125B Engineering IV, Univ. California, Los Angeles, CA 90024-1594 310-825-9490

Speech and Audio Processing, Trans.
Speech analysis, synthesis, coding speech recognition, speaker recognition, language modeling, speech production and perception, speech enhancement. In audio, transducers, room acoustics, active sound control, human audition, analysis/synthesis/coding of music, and consumer audio. (4)

Dan Kahn, Bell Comm Res., Room 2E-268, 445 South St., Morristown, NJ 07962-1910 201-829-4522

Systems, Man, and Cybernetics, IEEE Trans.
Large-scale systems, theory and applications; optimization; decision analysis; problem definition; modeling; simulation; testing; evaluation; foundations of cybernetics; pattern recognition; adaptive and learning systems; and biocybernetics. (6)

Andrew P. Sage, School of Information Technology & Engineering, George Mason University, 4400 University Dr., Fairfax, VA 22030 703-993-1500

Technology and Society Magazine
Impact of technology (as embodied by the fields of interest of IEEE) on society, including both positive and negative effects; the impact of society on the engineering profession, the history of the societal aspects of electrotechnology, and professional, social, and economic responsibility in the practice of engineering and its related technology. (4)

Norman Balabanian, 197 Babcock St. #2, Brookline, MA 02146 617-734-9830

Ultrasonics, Ferroelectrics and Frequency Control, IEEE Trans.
Acoustic holography and imaging; acousto-optic interactions; biological and medical applications; filters and resonators; industrial applications; nondestructive evaluation; physical acoustics; piezoelectric and magnetostrictive materials; surface-acoustic-wave-based systems; surface-acoustic-wave devices; and underwater sound. (6)
William D. O'Brien, Bioacoustics Research Lab, Dept. of Electrical & Computer Engineering, University of Illinois, 1406 West Green St., Urbana, IL 61801 217-333-2407

Vehicular Technology, IEEE Trans.
Land, airborne, and maritime mobile services; portable or hand-carried and citizen's communications services, when used as an adjunct to a vehicular system; vehicular electrotechnology, equipment, and systems ordinarily identified with the automotive industry. (4)
Sang B. Rhee, AT&T Bell Laboratories, Room 3B-310, Whippany Rd., Whippany, NJ 07981 201-386-6796

Very Large Scale Integration (VLSI) Systems, IEEE Trans.
Systems specifications, design and partitioning, high-performance computing and communication systems, neural networks, wafer-scale integration, and multichip module systems and their applications. (4)
Steve Kang, Coordinated Science Lab, Univ. Illinois, 1101 West Springfield, Urbana, IL 61801

Calendar

(Continued from p.17)
Washington, D.C.; James Bruorton, Kernet Electronics, Box 5928, Greenville, SC 29606; 803-963-6621; fax, 803-963-6521.

MAY

Custom Integrated Circuits Conference—CICC '94 (ED, SSC); May 1–4; Town & Country Hotel, San Diego, Calif.; Melissa Widerkehr, Widerkehr and Associates, Suite 610, 1545 18th St., N.W., Washington, DC 20036; 202-986-2166

Industrial & Commercial Power Systems Technical Conference—I&CPS (IA, Orange City); May 1–5; Radisson Plaza Hotel, Irvine, Calif.; Farrokh Shokooh, Electrical Engineering Operation Tech. Inc., C.O.A., 17870 Skypark Circle, Suite #102, Irvine, CA 92714; 714-476-8117.

International Conference on Communications—ICC Supercomm '94 (COM); May 1–5; Ernest N. Morial Convention Center, New Orleans, La.; Eddie Sawaya, South Central Bell Telephone Co., 365 Canal St., Room 710, New Orleans, LA 70140; 504-528-2673; fax, 504-528-7170.

International Symposium on Electronics and the Environment (TAB); May 2–4; San Francisco; Conference Registrar, IEEE Technical Activities, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331; 908-562-3878; fax, 908-562-1571.

Offshore Technology Conference—OTC '94 (OE); May 2–5; Astrodomain Complex, Houston, Texas; Deborah Wheeler, Box 833868, Richardson, TX 75083-3868; 214-952-9494; fax, 214-952-9435.

Conference on Lasers & Electro-Optics and the International Electronics Conference—CLEO/IQEC (LEO); May 8–13; Anaheim Convention Center, Anaheim, Calif.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331; 908-562-3893; fax, 908-562-1571.

International Conference on Robotics and Automation (RA); May 8–13; San Diego Princess Resort, San Diego, Calif.; Harry Hayman, Box 3216, Silver Spring, MD 20918; 301-236-5621; fax, 301-236-5621.

Electro '94 (Region 1, et al.); May 10–12; Hynes Convention Center, Boston; Sharon Schifano, Miller Freeman Inc., 13760 Noel Rd., Suite 500; Dallas, TX 75240; 800-527-0207; fax, 214-419-7915.

Instrumentation & Measurement Technology Conference—IMTC '94 (IM); May 10–12; Grand Hotel Hamamatsu, Hamamatsu, Japan; Robert Myers, Myers/Smith Inc., 3685 Motor Ave., Suite 240, Los Angeles, CA 90034–5750; 310-287-1463;.

International Conference on Computer Languages—ICCL '94 (C); May 16–19; University Paul Sabatier, Toulouse, France; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013; fax, 202-728-0884.

Microwave and Millimeter-Wave Monolithic Circuits Symposium (ED); May 23–24; San Diego Convention Center, California; Richard B. Gold, Pacific Monolithics, 245 Santa Ana Court, Sunnyvale, CA 94086-4512; 408-732-8000; fax, 408-732-3413.

Intelligent Networks Workshop—IN '94 (COM); May 24–26; Penta Hotel, Heidelberg, Germany; John Visser, Bell Northern Research, Box 3511, Station C, Ottawa, ON, KiY 4H7, Canada; 613-763-702.

International Microwave Symposium–MTT '94 (MTT); May 24–26; San Diego Convention Center, California; Mario Maury, 8610 Helms Ave., Cucamonga, CA 91730; 714-987-4715.

International Symposium on Atomic Layer Epitaxy and Related Surface Processes (ED); May 25–27; Sendai Memorial Hall, Sendai, Miyagi Prefecture, Japan; A. Koukitu, Secretary, ALE-3, Faculty of Technology, Tokyo University of Agriculture and Technology, Koganei, Tokyo 184, Japan; (81+423) 81 4221, ext. 336; fax, (81+ 423) 86 3002.

International Symposium on Industrial Electronics—ISIE '94 (IE); May 25–27; Catholic University of Chile, Santiago, Chile; Juan R. Pimentel, University of Politec. de Madrid, Disam, Jose Gutierrez Abascal, 2, 28006 Madrid, Spain; (34+1) 561 6989; fax, (34+1) 564 2961.

36th Cement Industry Technical Conference (IA); May 29–June 2; Westin Hotel, Seattle, Wash.; Stephen F. Sheridan, Ash Grove Cement Co., 6720 S.W. Macadam Ave., Suite 300, Portland, OR 97219-2312; 503-293-2333.

International Symposium on Circuits and Systems—ISCAS '94 (CAS); May 30–June 2; New Connaught Rooms, London; Robert Spence, Imperial College of Science, Technology and Medicine, Department of Electrical Engineering, Exhibition Road, London SW7 2BT, England; (44+71) 225 8505; fax, (44+71) 581 4419.

Microwave Conference—Mikon '94–X (Poland/AES, APC, MTT); May 30–June 2;

Ksiaz Castle, Warsaw, Poland; Edward Sedek, Mikon '94–Secretariat, Telecommunications Research Institute, Poligonowa 30, 00–991 Warsaw, Poland; (48+22) 1337 85; fax, (48+22) 1025 71.

Euronem '94 (AP); May 30–June 3; Palais Des Congrès, Bordeaux, France; M.V. Dhur, Euronem '94 Symposium, Centre d'Etudes de Gramat, 46500 Gramat, France; (33+65) 10 5406; fax, (33+65) 10 5433.

International Symposium on Power Semiconductor Devices and Integrated Circuits (ED); May 31–June 2; Convention Center, Davos, Switzerland; M. Ayman Shibib, AT&T Bell Labs, Box 13566, Reading, PA 19617-3566; 215-939-6576; fax, 215-939-6795.

International Symposium on Electron, Ion and Photon Beams (ED); May 31–June 3; Sheraton New Orleans Hotel, Louisiana; Harold Craighead, National Nanofabrication Facility, Cornell University, Knight Laboratory, Ithaca, NY 14853; 607-255-2329; fax, 607-255-8601.

Seventh International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems (C); May 31–June 3; Hyatt Regency Hotel, Austin, Texas; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013; fax, 202-728-0884.

JUNE

Frequency Control Symposium (UFFC); June 1–3; Boston Westin Hotel, Boston; Michael Mirarchi or Barbara McGivney, Synergistic Management Inc., 3100 Route 138, Wall Township, NJ 07719; 908-280-2024.

International Workshop on Numerical Modeling of Processes and Devices for Integrated Circuits—Nupad (ED); June 5–6; Hilton Hawaiian Village Hotel, Honolulu, Hawaii; Fely Barrera, Applied Electronics Laboratory 205, Stanford University, Stanford, CA 94305-4055; 415-723-1349; fax, 415-725-7298.

International Symposium on Electrical Insulation (DEI, Pittsburgh Section); June 5–8; Sheraton Station Square Hotel, Pittsburgh; Randy James, Oak Ridge National Laboratory, Building 3147, MS 6070, Box 2008, Oak Ridge, TN 37831; 615-574-6213; fax, 615-574-6210.

21st International Conference on Plasma Sciences—Icops (NPS); June 6–8; Sweeney Convention Center, Santa Fe, N.M.; Anthony L. Peratt, Los Alamos National Laboratory, Group p-15, MS D-406, Box 1663, Los Alamos, NM 87545; 505-667-1574; fax, 505-667-0401.

Technology Symposium (ED); June 7–9; Hilton Hawaiian Village Hotel, Honolulu, Hawaii; James T. Clemens, AT&T Bell Labs, 600 Mountain Ave., Murray Hill, NJ 07974; 908-582-2800; fax, 908-582-2793.

Vehicular Technology Conference—VTC (VT, Sweden Section, et al.); June 7–10; Stockholm International Fairs and Congress Centre, Stockholm, Sweden; Thomas Sidenbladh, Ericsson Radio Systems AB, S-164 80 Stockholm, Sweden; (46+8) 757 3844; fax, (46+8) 751 2309.

International Conference on Communication Technology—ICCT '94 (COM); June 8–10; Yangtze Hotel, Shanghai, China; Zhong Yunruo, China Academy of Posts and Telecommunications 40, Xueyuan Lu, Beijing 100083, China; (861+20) 11 624; fax, (861+ 20) 15 655.

Symposium on VLSI Circuits (SSC); June 9–11; Hilton Hawaiian Village, Honolulu, Hawaii; Charles Sodini, Massachusetts Insti-

Calendar

tute of Technology, Room 39–527B, Cambridge, MA 02139; 617-253-4938.

Seventh IEEE Symposium on Computer-Based Medical Systems—CBMS '94 (C, EMB, et al.); June 10–11; Stouffer Hotel, Winston-Salem, N.C.; Carla Muller, Bowman Gray School of Medicine, Department of Radiology, Medical Center Blvd., Winston-Salem, NC 27157-1022; 919-716-6890; e-mail, Carla@relito.medeng.wfu.edu.

International Symposium (AP); June 19–24; University of Washington, Seattle; Leung Tsang, Technical Program Chair, Department of Electrical Engineering, University of Washington, FT-10, Seattle, WA 98195; 206-685-7537; fax, 206-543-3842u.

Device Research Conference (ED); June 20–22; University of Colorado, Boulder; Joseph C. Campbell, Microelectronics Research Center, University of Texas, Austin, TX 78712; 512-471-9669; fax, 512-471-8576.

Sixth Joint Magnetism and Magnetic Materials—Intermag Conference (MAG); June 20–23; Albuquerque Convention Center, New Mexico; Diane Suiters, 6M^{3}I Conference, 655 15th St., N.W., Suite 300, Washington, DC 20005; 202-639-5088.

Antennas and Propagation Society International Symposium and URSI National Radio Science Meeting (AP); June 20–24; University of Washington, Seattle; Akira Ishimaru, University of Washington, Department of Electrical Engineering, FT-10, Seattle, WA 98195; 206-543-2169.

Conference on Computer Vision and Pattern Recognition (C); June 20–24; Westin Hotel, Seattle, Wash.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013; fax, 202-728-0884.

Power Electronics Specialist Conference—PESC '94 (PEL); June 20–24; International Convention Center, Taipei, Taiwan; T.C. Wang, National Tsing Hwa University, Department of Electrical Engineering, 855 Kuang-Fu Rd., Sec. 4, Taipei, Taiwan 300, China; (886+35) 715 131, ext. 4098; fax, (886+35) 715 971.

International Conference on Applications of Photonic Technology Sensing, Signal Processing and Communications—Icapt (Region 7, Toronto Section); June 21–23; Hilton International Hotel, Toronto; George A. Lampropoulos, A.U.G. Signals Ltd., 560 Lauder Ave., Toronto, ON, M6E 3J6, Canada; 416-658-6353.

International Conference on Applied Synergetics and Synergetic Engineering (ED); June 21–23; Fraunhofer Institute for Integrated Circuits, Erlangen, Germany; Thomas Wagner, Fraunhofer Institute, Department of Electronic Systems, Wetterkreuz 13, D-91058 Erlangen, Germany; (49+91) 31 776 544; fax, (49+91) 31 776 599.

13th International Conference on Consumer Electronics—ICCE (CE); June 21–23; Westin Hotel O'Hare, Rosemont, Ill.; Diane D. Williams, Conference Coordinator, 67 Raspberry Patch Dr., Rochester, NY 14612-2868; 716-392-3862.

International Conference on the Numerical Analysis of Semiconductor Devices and Integrated Circuits (ED); June 21–24; Daven Port Hotel, Dublin, Ireland; Paulene McKeever, Nasecode Secretariat, 26 Temple Lane, Dublin 2, Ireland; (353+1) 679 7655; fax, (353+1) 679 2469.

Seventh Workshop on Statistical Signal and Array Processing (SP); June 26–29; Le Chateau Frontenac, Quebec, Canada; Denis Gingras, National Optics Institute, 369

rue Franquet, Ste-Foy, Quebec, GIP 4N8, Canada; 418-657-7006; fax, 418-657-7009.

Third International Fuzzy Systems Conference (NN, Orlando Section); June 26–29; Walt Disney World Dolphin Hotel, Lake Buena Vista, Fla.; Nomi Feldman, Meeting Management Inc., 5665 Oberlin Dr., Suite 110, San Diego, CA 92121; 619-453-6222; fax, 619-535-3880.

International Symposium on Evolutionary Computation (NN, Orlando Section); June 26–July 2; Walt Disney World Dolphin Hotel, Lake Buena Vista, Fla.; Nomi Feldman, Meeting Management Inc., 5665 Oberlin Dr., Suite 110, San Diego, CA 92121; 619-453-6222; fax, 619-535-3880.

World Congress on Computational Intelligence (NN, Orlando Section); June 26–July 2; Walt Disney World Dolphin Hotel, Lake Buena Vista, Fla.; Nomi Feldman, Conference Coordinator, Meeting Management Inc., 5665 Oberlin Dr., Suite 110, San Diego, CA 92121; 619-453-6222; fax, 619-535-3880.

Conference on Precision Electromagnetic Measurements—CPEM '94 (IM); June 27–July 1; Clarion Harvest House Hotel, Boulder, Colo.; Gwen E. Bennett, NIST, 325 Broadway, Boulder, CO 80303; 303-497-3295.

International Symposium on Information Theory (IT); June 27–July 1; Technical University of Trondheim, Norway; Knut Grythe, Delab, N7034, Trondheim NTH, Norway; (47+75) 926 53; fax, (47+75) 943 02.

Power Modulator Symposium (ED); June 28–30; Westin South Coast Plaza, Costa Mesa, Calif.; J. Brooks, Palisades Inst., 2011 Crystal Dr., Suite 307, Arlington, VA 22202-3702; 703-486-7120; fax, 703-486-8527.

International Conference on Neural Networks (NN, Orlando Section); June 28–July 2; Walt Disney World Dolphin Hotel, Lake Buena Vista, Fla.; Nomi Feldman, Meeting Management Inc., 5665 Oberlin Dr., Suite 110, San Diego, CA 92121; 619-453-6222; fax, 619-535-3880.

American Control Conference—ACC '94 (CS); June 29–July 1; Stouffer Harbor Place Hotel, Baltimore, Md.; Hassan Khalil, Department of Electrical Engineering, Michigan State University, East Lansing, MI 48824; 517-355-6689; fax, 517-353-1980.

JULY

Fourth International Conference on Properties and Applications of Dielectric Materials—ICPADM (DEI); July 3–8; University of Queensland, Brisbane, Australia; Secretary ICPADM '94, Department of Electrical Engineering, University of Queensland, St. Lucia Brisbane 4072, Australia; (61+7) 365 3984; fax, (61+7) 365 4999.

Third International Symposium on Spread Spectrum Techniques and Applications—Isssta '94 (COM, IT, and the Finland Section); July 4–6; University of Oulu, Oulu, Finland; Pentti Leppanen, University of Oulu, Telecommunication Laboratory, Linnanmaa S1, SF-90570 Oulu, Finland; (358+81) 553 2838; fax, (358+81) 553 2845.

International Vacuum Microelectronics Conference (ED); July 4–7; World Trade Center Europole, Grenoble, France; D. Celier, Société Française Du Vide, 19, rue du Renard, 75004 Paris, France; (33+1) 42 78 15 82; fax, (33+1) 42 78 63 20.

Second Biennial European Joint Conference on Engineering Systems Design and Analysis (C); July 4–July 7; University of London, Great Britain; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1992; 202-371-1013; fax, 202-728-0884.

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EEs' tools & toys

Lightweight unit combines autoranging scope, DMM

One offshoot of the spread of electronic controls in industry is that electricians and other personnel with little formal training in this field are having to install and service rather complicated electronic equipment. To help them make the measurements those tasks require, Tektronix Inc. is coming out with a family of smart portable instruments it calls TekTools, the first of which is the 1-kg TekMeter. Combining a 5-MHz oscilloscope with a 3¾-digit (3999-count) digital multimeter (DMM), the TekMeter has been designed specifically for easy use by nonprofessional personnel.

To that end, the TekMeter in its oscilloscope mode features both automatic setup and automatic ranging—that is, it not only sets its sweep rate and vertical attenuation when it first displays a signal, but continually tracks the signal and adjusts its scale factors whenever the signal changes significantly. The result is hands-off waveform observation by even unskilled personnel.

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So, to make sure that those users get their data quickly, even though the TekMeter has only a 5-MHz scope, it runs its front-end analog-to-digital converters at 20 megasamples per second. That provides enough points for a waveform to be displayed without waiting for multiple signal cycles.

Furthering the instrument's

(Continued on p. 91)

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For immediate consideration, please send your resume to: Professional Staffing, MS 55-545, Tektronix, Inc., P.O. Box 500, Dept. SP0194-RE/GF, Beaverton, OR 97077. We support a drug-free work environment and all employment offers are contingent upon successful completion of our pre-employment drug test. Tektronix is an equal opportunity/affirmative action employer and encourages diversity in the workplace.

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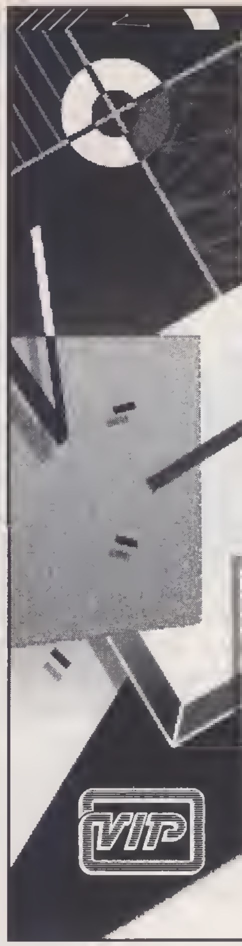

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Please submit resume or Federal application (SF-171) no later than Feb.15,1994 to: Ms. Kathy Schmidt, U.S. Nuclear Regulatory Commission, 2104-MNB, (Dept. A-94004), Washington, D.C. 20555. An equal opportunity employer, M/F/D/V. U.S. citizenship required.

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DEAN OF THE COLLEGE OF ENGINEERING NORTH CAROLINA STATE UNIVERSITY

North Carolina State University invites applications and nominations for the position of Dean of the College of Engineering.

The Dean, as chief executive officer of the College of Engineering, provides leadership for large, high-quality programs in education, research, and extension. The College is one of the largest in the country, with average annual enrollments of approximately 6,000 undergraduates and 1,200 graduate students. Of the 423 faculty and research staff members, 210 are tenure-track faculty members. The 10 departments offer 17 BS, 17 MS, and 15 Ph.D degree programs. Annual research contracts and grants exceed $28M; total research expenditures exceed $38M annually. Substantial interdisciplinary research is conducted under the auspices of large, well-supported research centers and institutes including the Center for Communications and Signal Processing, the Center for Transportation and the Environment, the Integrated Manufacturing Systems Engineering Institute, the Mars Mission Research Center, the NSF Engineering Research Center for Advanced Electronic Materials Processing, and the Precision Engineering Center.

Candidates must have an earned doctoral degree in engineering or related field; distinguished performance in education, research, and administration; communication skills; ability in fund raising activities; and a demonstrated commitment to education, research, and extension. **Being an Affirmative Action, Equal-Opportunity Employer, North Carolina State University eagerly seeks applications and nominations of members of underrepresented groups.**

Review of applications will begin February 1, 1994, and will continue until the position is filled. Send resume, cover letter and three references to:

Dr. Robert Clark
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Washington watch

(Continued from p. 14JT)

media "data superhighway" network.

On pensions, the IEEE-USA has provided $200 000 to help craft a pension reform bill, which Representative George E. Brown Jr. (D-Calif.), chairman of the House Science, Space, and Technology Committee, is introducing in the House of Representatives. (Last year, the Senate failed to act on it.)

The IEEE group has also focused on U.S. patent law, which, IEEE-USA's David M. Ostfeld told the U.S. Patent and Trademark Office in October, should be changed to coincide with that of most other nations. The "first-to-invent" system should be supplanted by a "first-to-file" one, he said, which should make U.S. inventors more aggressive in global markets. More information is available from IEEE-USA at 202-785-0017.

Savings in electric motor control

All kinds of cooperative agreements are afoot these days. One neglected by the popular media involves the U.S. Department of Energy (DOE) and some 40 users and suppliers of electric motor and drive systems.

This is an industry-driven efficiency effort that, by the year 2000, could save about $2 billion of the $30 billion spent annually in the United States on electricity for motors, according to DOE Secretary Hazel O'Leary. The electricity generated to drive the motors also is responsible for 8 percent of total U.S. carbon emissions. Taxpayers will spend $6 million on the effort in 1994 and 1995. Industry may spend at least $15 million. For more information, contact DOE's Paul Scheihing at 202-586-7234.

Messages to Bill

Now is your chance to affect the quality of advice reaching the President. Sending e-mail to the White House is possible from a variety of services, including even from a new exhibit at The Computer Museum, Boston. From America On-Line, the address is "Clinton PZ"; on CompuServe, it is 75300,3115; on GEnie, it is "WHITEHOUSE"; on MCI Mail, it is "White House" or MCI ID 589-5485; on ZiffNet, it is "Go ZNT:EXEC."

On Internet, the White House can be reached through the Information Age moniker: "President@Whitehouse.gov". Most of the services also have White House information sections if you really want to read daily transcripts of the Administration's media announcements and press briefings.

Paper is still popular, though. Each day, the White House gets some 6000 letters written the old fashioned way—on paper—compared to about 1000 digital ones.

John A. Adam Washington Editor

Dean, Engineering & Computer Science
California State University Sacramento

CSUS invites applications and nominations for Dean, School of Engineering and Computer Science. The anticipated starting date is August 1, 1994. Salary and benefits are competitive.

The Dean is responsible for the curricular, fiscal, and personnel management of the School, including support of faculty scholarship and service activities, external fund development, and long-range planning.

Applicants must have an earned doctorate or equivalent terminal degree and be eligible for a senior faculty appointment within the School, demonstrated administrative experience in engineering or computer science, successful fiscal resource management experiences, including raising external funds, and strong interpersonal skills, including interaction with diverse groups and populations.

Nominations accepted until January 21, 1994. Review of applications will begin on January 28, 1994. Applications should include a cover letter, current vitae, names, addresses, and telephone numbers of three references. The search will remain open until an appointment is made.

All materials should be sent to:

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Memphis State University

DEAN, HERFF COLLEGE OF ENGINEERING

Memphis State University invites applications and nominations for the position of Dean of the Herff College of Engineering. Candidates must hold an earned doctorate in an engineering discipline and have a record of teaching, research, and service commensurate with appointment at the full professor level. Engineering registration is preferred. Candidates should have appropriate administrative experience and demonstrated leadership skills in an academic environment as well as a record of attracting significant external support. The Dean will represent the college within the university environment and to the engineering profession, and will interact with local/regional government, industry and the Memphis community. A commitment to fund-raising to support the college mission is a necessity. Personal qualifications should include strong decision-making skills, management/budgeting expertise, the ability to work with and motivate people, and a commitment to quality.

Memphis State University is one of two public comprehensive doctoral granting institutions in Tennessee. Through its nine colleges and schools, the University enrolls approximately 20,000 students, of which 4,400 are in graduate programs.

The Herff College of Engineering offers ABET accredited Baccalaureate programs in Civil, Electrical, and Mechanical Engineering, and Engineering Technology with Masters degree programs in Biomedical, Civil, Electrical, Mechanical, and Industrial Systems Engineering and Engineering Technology, and a Ph.D. program with specialization in Biomedical, Civil, Electrical, and Mechanical Engineering. Over 1300 undergraduate and 250 graduate students are enrolled in the college. Annual research expenditures have been increasing significantly and in 1992-93 awards totaled $2.3 million. The Dean reports directly to the Provost and provides leadership to 60 faculty.

Memphis State University is strongly committed to diversity; women and minority candidates are encouraged to apply. Review of nominations and applications will begin February 1, 1994, and will continue until the position is filled. Application materials should include a statement of interest, full curriculum vitae, and names of three references, including addresses and telephone numbers. All materials should be sent to:

Dr. Martin E. Lipinski, Chair
Search Committee, Dean of Herff College of Engineering
Office of President
313 Administration Building
Memphis State University
Memphis, Tennessee 38152

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Tools & toys

(Continued from p. 90)

appeal to those unfamiliar with oscilloscopes, the TekMeter is designed always to power up as a DMM. If a user wants a scope, he or she presses a single button, and the large liquid-crystal display becomes a scope face.

Because of its all-digital architecture, the TekMeter can do a great deal of processing of the signals it acquires. The two-channel version, for example, can calculate and display instantaneous power; compute power transformer harmonic derating factors; and automatically detect and capture power-line disturbances. Future TekTools—say, for the automotive or telecommunications fields—will be based on the TekMeter, and will differ only in their firmware. For low-volume applications, Tektronix may sell development kits with which third-party suppliers could design testers for niche markets.

The TekMeter comes in three versions: the single-channel 550, the dual-channel 560, and the dual-channel 565 with backlighting and date stamping. Prices are US $859, $999, and $1259, respectively. *Contact: Tektronix Inc., Box 1520, Pittsfield, MA 01202; 800-426-2200; or* **circle 100.**

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O-Matrix is a 32-bit object-oriented analysis and visualization package for performing numerical analyses on IBM-type personal computers. It is a matrix-based tool with over 100 built-in features, including algebraic and trigonometric functions, Fourier and inverse Fourier transforms, and Bessel functions. It also offers QR factorization, singular value decomposition, Runge-Kutta and Pade differential equation solvers, Cholesky factorization, and many more functions.

The package, from Harmonic Software, uses extended memory, which allows matrices and programs of up to 32 MB. But perhaps its most noteworthy aspect is its price—just $95, including documentation and unlimited technical support. At a minimum, O-Matrix requires a computer with a 386 microprocessor, MS-DOS 3.3, 1 MB of RAM, and 3 MB of free disk space. *Contact: Harmonic Software, 12223 Dayton Ave. N., Seattle, WA 98133; 206-367-8742; Internet, harmonic@world.std.com; or* **circle 101.**

Working on more than one computer

The trouble with having two or more computers—say, one at home and another at the office—is in keeping them coordinated. Ideally, you want them to be identical, to have the same directory structure and files, so each acts as if it's your only computer. But after a session on one, how can you conveniently and easily update the other?

The answer is with Frisbee, a connectivity package from Polyhedron Software Ltd. With Frisbee, you simply type THROW at the end of a session on one machine, and the program figures out which files and directories have been created, changed, or deleted. Then it copies those changes into a compressed archive on one or more diskettes.

Type CATCH at the second machine, and Frisbee reproduces all the changes, allowing you to continue your work on the second computer as though you were still at the first. The program works with any IBM-type PC, even old 8088 machines, and takes up about half a megabyte of disk space.

It sells for UK £40, plus shipping. Until Jan. 31, 1994, it is also being offered for US $69.99, including shipping to North America but not local taxes. *Contact: Polyhedron Software Ltd., Linden House, 93 High St., Standlake, Witney OX8 7RH, United Kingdom; (44+865) 300579; fax, (44+865) 300232; Compuserve, 100013,461; or* **circle 102.**

COORDINATOR: Michael J. Riezenman
CONSULTANT: Paul A.T. Wolfgang, Boeing Defense & Space Group

Circle No. 20

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

ADVERTISING RATES

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Positions wanted—$40.00 per line, a 50% discount for IEEE members who supply their membership numbers with advertising copy.

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IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

Academic Positions Open

Brigham Young University. Computer Science Department, Assistant Professor. Applications are invited for an Assistant Professor position beginning September, 1994. Applicant must have a PhD and should have strong research orientation and scholarly ability. Current areas of research in our PhD and MS programs include User Interfaces, Neural Networks, MultiMedia, Communications/Networking, Software Engineering, Robotics, and Computer Vision. The Computer Science Department is housed in a new 54,000 square foot facility with well equipped teaching and research laboratories. Applicants should send a curriculum vita to E. Daniel Johnson, 3362 TMCB, Brigham Young University, Provo, Utah 84602. BYU is an EEO/AA employer and is sponsored by the Church of Jesus Christ of Latter Day Saints.

Princeton University: The Department of Electrical Engineering invites applications for a full time, tenure-track, junior or senior faculty position. The areas of particular interest are Computer Architecture, Parallel Processing, and other closely related disciplines in Computer Engineering. Please send a complete resume, a description of research and teaching interests and names of three references to Professor Stuart Schwartz, Chairman, Dept. of EE, Princeton University, Princeton, NJ 08544. Affirmative Action/Equal Opportunity Employer.

University of Illinois at Chicago. The Department of EESC invites applications for tenure-track faculty positions at both junior and senior levels. Applications for instructorships are also invited. A PH.D. in electrical engineering, computer science, or equivalent is required by date of appointment (except for instructorships). Candidates should have outstanding research and teaching potential. UIC is one of four Research-I Universities in the state of Illinois. The EESC Department has 50 faculty members and about 500 graduate students in EE and CS. Send a resume and the names of at least three references by March 31, 1994 to Dr. Roger Conant, Search Committee Chair, Department of EECS (M/C 154), The University of Illinois at Chicago, 1120 Science & Engineering, 851 South Morgan Street, Chicago, Illinois 60617-7053. The University of Illinois at Chicago is an Affirmative Action/Equal Opportunity Employer.

San Jose State University, Electrical Engineering Department. Applications are invited for a tenure-track faculty position. Assistant Professor applicants are particularly encouraged to apply. The position is available in microelectronic VLSI/ULSI circuit design, semiconductor devices and technologies. Earned doctorate in Electrical Engineering is required. The position is limited to U.S. citizens or permanent residents. Research, consulting and summer employment opportunities are available. The University is the oldest and one of the largest in the California State University System. It is located at the southern end of San Francisco Bay in the heart of Silicon Valley. Resume and names and addresses of three references should be submitted to Dr. Ray R. Chen, Chair, Department of Electrical Engineering, San Jose State University, San Jose, CA 95192-0084. San Jose State University is an equal opportunity/affirmative action/Title IX employer. Women and minorities are especially encouraged to apply.

University of South Carolina. NCR Endowed Chair in Computer Engineering. The University of South Carolina Department of Electrical and Computer Engineering seeks applications for the NCR Endowed Chair position in Computer Engineering at the rank of Professor. Applicants must have demonstrated research success in computer architecture, software systems or a related field. The selected individual will be expected to work closely with the department's faculty and NCR (an AT&T Company). The relationship between NCR and the department is strong, with NCR supporting several research efforts. The ECE Department is housed in the $24 million Swearingen Engineering Center. The B.S., M.E., M.S., and Ph.D. degrees are offered by the department. Interested individuals should submit a resume, a publication bibliography, names of five references, and three selected publications by March 1, 1994 to: NCR Chair Search Committee, Department of Electrical and Computer Engineering, University of South Carolina, Columbia, SC 29208. The University of South Carolina is an equal opportunity and affirmative action employer.

The Department of Electrical Engineering and Computer Engineering of the University of Southwestern Louisiana seeks candidates for faculty positions in Communications, Systems, Information Theory, Communications Networks, and Signal Processing. Applicants must show promise for high quality research in view of the increasing emphasis on research at U.S.L. The Department offers B.S., M.S., and Ph.D. degrees and is affiliated with the Center for Advanced Computer Studies. Total annual research funding is $800,000. Substantial funding for research is available through the Louisiana Education Quality Support Fund. A special focus program on Telecommunications is offered. This program has a strong relationship with industry. USL has the highest percentage of African American students (18%), and strives to achieve diversity among its students and faculty, within a progressive environment. Women and minorities are especially encouraged to apply. Send CV to: D. Kazakos, Head of EECE Department, P.O. Box 43890, USL, Lafayette, LA 70504-3890. Tel: (318) 231-6568. E-mail: kazakos@usl.edu.

Electrical Engineering: University of North Carolina at Charlotte. Applications are invited for a tenure-track position at the Assistant or Associate Professor level in any research discipline of Communications and Signal Processing to begin in Fall of 1994. Candidates at the rank of Assistant Professor should have a high potential for both teaching and research. Candidates for Associate Professor should have both a strong research record and dedication to educational programs. UNC-Charlotte is one of the largest institutions of the UNC systems, with approximately 16,000 students in six colleges. The program is fully accredited with 20 faculty members and offers B.S., M.S., and Ph.D. degrees. The research and teaching facilities include 200 networked workstations, and free access to a Cray YMP Supercomputer. Applicants must have a Ph.D. degree or equivalent. Rank and salary are commensurate with experience. Applications will be accepted until the position is filled. Applicants should send a cover letter, resume, and a list of four references to: Prof. V.P. Lukic, Chairman, Search Committee, Electrical Engineering Department, UNC-Charlotte, Charlotte, NC 28223. UNC-Charlotte is an AA/EOE.

Electrical Engineering and Computer Science: Tufts University seeks three faculty members to join the Electrical Engineering and Computer Science Department which was recently formed by the merger of Electrical Engineering and Computer Science. The Department invites applications for one tenure track position of Full Professor and two tenure track positions of Assistant Professor, duties to begin September 1, 1994. All candidates must have a Ph.D. in Computer Science, Computer Engineering, or a closely related field. Preference will be given to candidates who can strengthen its research efforts in high performance computing, computational science, parallel computing, artificial intelligence, VLSI CAD. The successful candidate for the position of Full Professor must show exceptional scholarship and have a proven record of attracting sustained research funding. This person is expected to provide leadership in research and graduate education. For an appointment as Assistant Professor, an applicant must have a documented potential for research, and an interest in teaching students at all levels. A normal teaching load at Tufts is 4 courses a year. Tufts is an affirmative action, equal opportunity employer. Resumes should be sent to Denis W. Fermental, Electrical Engineering & Computer Science, 161 College Ave., Medford, MA 02155 by March 1, 1994.

Rice University Department of Electrical and Computer Engineering invites applications for a tenure-track faculty position in the broad area of telecommunication and communication networks, to begin in August 1994. Applicants must have a doctorate in Electrical Engineering, or a closely related field. Rice University is a small private university with a strong commitment to excellence in both research and teaching. The ECE Department has extensive computing and laboratory facilities. The Department of Electrical and Computer Engineering has close ties and active collaboration with the Department of Computer Science and the Department of Computational and Applied Mathematics. Applicants should submit their resume, a summary of their research accomplishments, and the names of at least three references to the Chairman of the Department of Electrical and Computer Engineering, Rice University, P.O. Box 1892, Houston, TX 77251-1892. Rice University is an equal opportunity/affirmative action employer.

Iowa State University. The Department of Electrical Engineering and Computer Engineering invites applications for several tenure-track faculty positions. Applicants at all ranks will be considered. Starting dates are negotiable with preference given for Fall 1994. Primary needs are for specialization in the areas of analog VLSI, communications, signal processing, computer networks, distributed computing, real-time systems, and microelectronics. Responsibilities include teaching, research, and outreach. Salary and rank are commensurate with qualifications and experience. Requirements include a doctorate degree with a demonstrated potential for success in research and teaching. Applicants should send a resume with a statement of teaching, research, and outreach interests, as well as a list of three (3) references to: Chair, Faculty Search Committee, Department of Electrical Engineering and Computer Engineering, Iowa State University, Ames, Iowa 50011. Interviews will commence after February 1, 1994. Iowa State University is an Equal Opportunity/Affirmative Action Employer.

The University of Cincinnati Electrical and Computer Engineering Department. Applications are solicited for tenure track Assistant/Associate Professor faculty positions in the Department of Electrical and Computer Engineering starting January/September, 1994. Applicants in the following areas are of special interest: (1) Computer System Design, including programming languages, compiler design, networks, software

engineering, parallel and distributed computing, operating systems, databases, architecture, computation theory, and VLSI systems design, test, verification, and VLSI CAD tool development; (2) Intelligent Systems and Informatics, including computer vision, artificial neural network-based systems, manufacturing and discrete-event systems, automatic factory control, intelligent control systems, and micro-electromechanical systems, including micro-sensors, micro-machining, and integrated circuit design for smart sensing; (3) Microwave and millimeter wave devices, circuits, and systems, and photonic and optoelectronic devices, circuits and systems. The Department offers MS/Ph.D. programs in electrical engineering, computer engineering, and computing sciences as well as an ABET fully-accredited undergraduate program in Electrical and Computer Engineering. The Department has 30 full-time faculty, 200 full-time graduate students, 400 undergraduate students and graduates 35 M.S. and 15 Ph.D.s per year. The Department is very well equipped in both teaching and research labs with state-of-the-art networked computing facilities. The University is supportive of the Department in providing an environment conducive to the establishment of an academic and professional career. All candidates should have an earned Ph.D. in Electrical Engineering, Computer Engineering or Computer Science. Please send curriculum vitae and the names of three references to: Prof. Vik J. Kapoor, Head, Electrical and Computer Engineering Department, Mail Location 30, University of Cincinnati, Cincinnati, Ohio 45221-0030 (e-mail vkapoor@uceng.uc.edu). The University of Cincinnati is an Affirmative Action/Equal Opportunity employer and encourages and welcomes applications from women and minorities.

Electrical Engineering: Two tenure-track positions at Cedarville College. An accredited undergraduate Baptist College of the arts, sciences, and professional programs of 2,300 students, combining a balanced liberal arts focus with a fundamental theological position in doctrine and lifestyle with which our faculty, who must be Christians, must agree. Each primarily teaching Communications Theory with courses in two of the following: (1) electromagnetics, modulation, and propagation; (2) information theory; (3) digital systems. Each also will supervise senior design projects. Positions available Winter or Spring Quarter 1994. Rank and salary commensurate with degrees and experience. Send letter of application and resume to Dr. Duane R. Wood, Academic Vice President, Cedarville College, P.O. Box 601, Cedarville, Ohio 45314. Cedarville College is an equal opportunity employer.

Thomas J. Watson School of Engineering & Applied Science. The Department of Electrical Engineering of the State University of New York at Binghamton invites applications for two tenure-track faculty positions at the Assistant Professor level in the areas of: Computer Engineering (Systems Integration/Architectures) and Power Electronics. A Ph.D. in Electrical Engineering or a closely related field is required. Successful applicants will be expected to teach appropriate undergraduate and graduate courses, develop active research programs in conjunction with other faculty in the area, and supervise MS and Ph.D. research. The Department is an active partner in the Integrated Electronics Engineering Center, an NSF supported state/industry/university research center and New York State Center for Advanced Technology, focused on electronics packaging research. Applications, including a full resume, copies of recent publications, and the names of three references (with telephone numbers) should be sent to: Dr. James Morris, Chairman, Department of Electrical Engineering, Watson School, Binghamton University, Binghamton, NY 13902-6000. Fax (607) 777-4000. An equal opportunity employer, The State University of New York at Binghamton is strongly committed to affirmative action. Recruitment is conducted without regard to race, color, sex, religion, age, disability, marital status, sexual orientation or national origin.

Harvard University. We invite applications from candidates at all levels for a faculty position in Electrical Engineering. Individuals with interests in the areas of electronics or communications/computer engineering are sought. Candidates should have an interest in design and fabrication at the device or systems level and have a Ph.D. in Electrical Engineering, Computer Engineering, or a related discipline. Responsibilities include teaching in the AB., S.B., and Ph.D. programs and having a strong research commitment. Applicants should submit a curriculum vitae and the names, addresses and telephone numbers of three references to the EE/CS Search Committee, Pierce Hall 217, Harvard University, 29 Oxford Street, Cambridge, MA 02138. Applications should be received by February 28, 1994. Harvard is an Equal Opportunity/Affirmative Action employer and encourages applications from women and members of minority groups.

Mississippi State University invites applications for tenure-track faculty positions in the Department of Electrical & Computer Engineering. Applicants should have a strong background in one of the following areas: (1) computer architecture, (2) computer system design, (3) high-performance digital electronics, (4) digital signal processing, (5) analog electronics, (6) optoelectronics, or (7) computational electromagnetics (experience in finite-difference time-domain methods required). One area of particular interest is signal processing applications in Ocean Acoustics. Several of these positions are in conjunction with the MSU/NSF Engineering Research Center for Computational Field Simulation which is one of the nation's 18 NSF Engineering Research Centers. A Ph.D. and a strong interest in graduate and undergraduate teaching are required. Individuals will be expected to demonstrate ability to conduct sponsored research in one of the above areas. Salary and rank commensurate with qualifications. A more detailed description of each position can be obtained by writing to the address shown below or sending e-mail to position@ee.msstate.edu. Applications will be accepted through February 15, 1994, or until positions are filled. Send resume and list of three references to Dr. G.M. Molen, Department of Electrical and Computer Engineering, P.O. Drawer EE, Mississippi State, MS 39762. MSU is an affirmative action, equal opportunity employer.

Faculty Positions, Massachusetts Institute of Technology. The Department of Electrical Engineering and Computer Science seeks candidates for faculty positions starting in September 1994. We anticipate openings for several junior faculty appointments for individuals who are completing, or who have recently completed, a doctorate. Faculty duties include teaching at both the graduate and undergraduate levels, research, and supervision of theses. We are interested in candidates in most areas of electrical engineering and computer science. All candidates should write to the address below, describing their professional interests and goals. Each application should include a curriculum vitae and the names and addresses of three or more references. Additional material describing the applicant's work, such as papers or technical reports, would also be helpful. All candidates should indicate citizenship and, in the case of non-US citizens, describe their visa status. Please respond by February 18, 1994. Send all applications to: Prof. F.C. Hennie, Room 38-435, Massachusetts Institute of Technology, Cambridge, MA 02139. M.I.T. is an equal opportunity/affirmative action employer.

Electrical Engineering Faculty Positions, Penn State. Applications are invited for tenure-track faculty positions in the Department of Electrical Engineering at The Pennsylvania State University. Candidates should have a Ph.D. in Electrical Engineering or related discipline, the ability to establish a strong research program, and the desire to teach at both the undergraduate and graduate levels. Although candidates in all areas will be considered, the top priority is for a person at the full professor level in applied communications, with emphasis in one or more of the following areas: video signal transmission and reception, fiber optics communication, microwave communication, and active/passive remote sensing. Candidates at the assistant professor level will be considered in all areas. The Department of Electrical Engineering at Penn State currently has over 45 faculty, 600 junior and senior level students, and 200 graduate students. Funded research is being conducted in many areas, including: Electromagnetics, Space Science, Electro-optics, Signal Processing, Digital Systems, Power, Electronic Materials and Processing, Communications, and Control. Please send resumes and cover letters, with names, addresses and phone numbers of at least three references, to: Personnel Committee, Department of Electrical Engineering, Box IEEE, 129 EE East, The Pennsylvania State University, University Park, PA 16802. Applications received by January 31, 1994, will be assured of consideration; however, applications will be considered until the positions are filled. An Affirmative Action/Equal Opportunity Employer. Women and minorities encouraged to apply.

University of South Florida Department of Electrical Engineering invites applications for a tenure-track assistant or associate professor position beginning fall 1994. Earned PhD in Electrical Engineering or closely related discipline required. Experience and interest in one or several of the following areas is important: Microwave/mm-wave semiconductor devices, EM circuit analysis, Quasi-optics, Optical/microwave sub-systems, Microwave systems. Industrial experience and a record of initiating and obtaining support for research projects and/or instructional advances preferred. Demonstrated ability to teach state-of-the-art courses and pursue research both as individual investigator and as team member on larger programs desired. Applications, resume and a minimum of three references should be mailed to Secretary, Faculty Search Committee, Department of Electrical Engineering, USF, Tampa, FL 33620 by February 28, 1994. Phone: (813) 974-2369. The University of South Florida is an Equal Opportunity/Affirmative Action Employer.

University of South Florida Department of Electrical Engineering invites applications for a tenure-track assistant, associate or full professor position in the area of Electrical Power Systems beginning fall 1994. Earned PhD in Electrical Engineering or closely related discipline required. Experience and interest in control and conversion of electric power, power delivery and energy management is desirable. Applications, resume and a minimum of three references should be mailed to Secretary, Faculty Search Committee, Department of Electrical Engineering, USF, Tampa, FL 33620 by February 28, 1994. Phone: (813) 974-2369. The University of South Florida is an Equal Opportunity/Affirmative Action Employer.

Graduate Fellowships and Research Associates. Fellowships and Associateships are available for M.S. or Ph.D. students in Electrical Engineering. Fellowships provide a nine-month stipend of $15,000 for Ph.D. students and $12,000 for M.S. students plus tuition waiver. The stipend for Research Associates is $8,000 for nine months plus tuition waiver, and requires research duties under the direction of a faculty member. Applicants must be U.S. citizens and posses a B.S.E.E. or M.S.E.E. from an engineering department that has a basic or advanced program that is ABET accredited. Minimum undergraduate GPA's are 3.5/4.0 for a Fellowship and 3.1/4.0 for Associateships. For consideration, send a brief resume and transcripts before March 1, 1994 to: Dr. Jeffrey Giesey, Dept. of Electrical and Computer Engineering, 335 Stocker Center, Ohio University, Athens, OH 45701-2979.

Chair Search Announcement, Department of Computer Science & Engineering, Wright State University. Wright State University invites nominations and applications for the position: Chair of the Department of Computer Science & Engineering. The Department resides in the College of Engineering and Computer Science, and offers BS, MS, and PhD programs in both Computer Science and Computer Engineering. Candidates are expected to have an earned PhD in computer science, computer engineering, or a closely related field, and have a distinguished record in computing that demonstrates strong leadership in both research and teaching. The Computer Science & Engineering Department is one of four departments in the College of Engineering and Computer Science. The Department currently has 21 faculty members, 380 undergraduate majors, and 130 graduate students. It is housed in a new, attractive, engineering building with a fully networked Unix environment and excellent laboratories. Areas of active research include artificial intelligence, image processing,

CLASSIFIED EMPLOYMENT OPPORTUNITIES

database, parallel processing, programming languages and compilers, robotics, and software engineering. Wright State University, an institution of 17,000 students, is located on a spacious campus with a significant area of protected green space, in a rapidly growing high-tech suburban community, and is surrounded by commercial and government research and development facilities. A significant portion of the Department graduate students come from these facilities. The University is proactively committed to industrial and government partnerships for research and development ventures. A variety of affordable, pleasant living environments, attractive to professionals and their families, are located convenient to the campus. Applications should include a vitae, a brief statement of research and teaching interests, copies of three publications representing the candidate's strongest contributions, names of three references who are sending recommendations directly to the Search Committee, and any additional important supporting information. The salary is competitive. Address applications and supporting information to: Chair, Search Committee, Department of Computer Science & Engineering, Wright State University, Dayton, OH 45435. Consideration of candidates will begin February 1, 1994 and continue on the first of each month until July 1, 1994 or until the position is filled. Wright State University is an equal opportunity/affirmative action employer.

Faculty Positions in Computer Science-GMI Engineering & Management Institute invites applications for tenure-track positions in Computer Science. These positions are at the Assistant or Associate Professor level, dependent upon the qualifications and experience of the candidate. GMI operates on a five-year fully cooperative plan of undergraduate education, offering Bachelor degrees in Applied Mathematics, Electrical Engineering, Industrial Engineering, Management, Manufacturing Systems Engineering, and Mechanical Engineering. GMI is now seeking to offer a degree in Computer Science which will take advantage of our coop program and applied focus. The minimum qualifications for these positions include an earned Ph.D. in Computer Science, experience in and commitment to undergraduate teaching, and effective communication skills in the English language. Experience in industry or in curriculum development is highly desirable. Preference will be given to candidates with expertise in the areas of software engineering, computer networks, operating systems, compilers, and information retrieval. The individuals hired will be expected to participate in curriculum development, teach a variety of courses, continue their research and professional development, interact with colleagues in a multidisciplinary environment, advise students, and participate in service activities. To apply, send resume and names, addresses, and phone numbers of three references to: Dr. Jo Smith, Computer Science Search Committee Chair, Science and Mathematics Department, GMI Engineering & Management Institute, 1700 W. Third Avenue, Flint, Michigan 48504-4898. Review of applicants will commence immediately. To ensure full consideration, applications must be received by February 15, 1994. The appointments will commence July 1, 1994. GMI is an equal opportunity employer; minorities and women are encouraged to apply. Candidates must have proof of legal authority to work in the U.S. GMI is a smoke-free facility.

Santa Clara University, Assistant Professor position in Electrical Engineering. The Department of Electrical Engineering seeks applicants for a tenure track position in electrical circuits and/or networks. Candidates must have a PhD in Electrical Engineering with a research background in electrical circuits and/or networks or a closely related area. Santa Clara University located in Silicon Valley, near San Jose and about 50 miles south of San Francisco. It is a comprehensive university with a particular emphasis on excellence in teaching at the undergraduate level. The Electrical Engineering Department also takes part in a large part-time MS program and has a modest PhD program. The department has 14 full-time faculty members and some 50 part-time instructors in the graduate program. The successful candidate will be involved in teaching of electric circuits courses at the undergraduate level, teaching and supervision of lecturers in specialty areas at the graduate level, and will be expected to carry on research in the area of circuits and/or networks or a closely related area. Santa Clara is an equal opportunity/affirmative action employer, committed to excellence through diversity, and in this spirit, particularly welcomes applications from women, persons of color, and members of other historically underrepresented U.S. ethnic groups. Candidates should send a curriculum vita and at least three references to Prof. R.B. Yarbrough, Faculty Search Committee, Electrical Engineering, Santa Clara University, Santa Clara, CA 95053. To be considered, applications must be received by March 1, 1994.

Stevens Institute of Technology, Department of Electrical Engineering and Computer Science. The Department of Electrical Engineering and Computer Science (EECS) at Stevens Institute of Technology invites applications for tenure-track faculty positions at all levels. Applicants should have a Ph.D. in Electrical Engineering, Computer Engineering or Computer Science and should show evidence of exceptional research and teaching promise. Senior level candidates should have a record of distinguished research and teaching. The EECS Department is currently seeking applicants in telecommunications: high speed multimedia networking (ATM and broadband ISDN), network management, wireless communications and multimedia applications. Applicants are also sought in computer architectures and digital systems, operating systems, software engineering, artificial intelligence, parallel and distributed computing, database management and computer graphics and imaging. Stevens Institute of Technology, founded in 1870, is located in Hoboken, New Jersey on the west bank of the Hudson river directly across from Manhattan, NY. Stevens has recently established an Advanced Telecommunications Institute (ATI), a national center for applied research in telecommunications. The EECS Department offers Bachelor's (programs are accredited by ABET and CSAB), Master's, Engineer's and Ph.D. degrees. Send your vita, with the names of four references, to: Prof. D.R. Vaman, Chairman, Faculty Search Committee, Department of Electrical Engineering and Computer Science, Stevens Institute of Technology, Castle Point on the Hudson, Hoboken, NJ 07030 (dvaman@vaxc.stevens-tech.edu). Stevens is an Affirmative Action/Equal Opportunity employer.

Industrial and Management Systems Engineering. Assistant/Associate tenure-track faculty position for '94-95 A/Y. The individual will be expected to teach and do research in traditional and non-traditional manufacturing processes and systems. This person will support the CIM laboratory and the College thrust for microelectronics manufacturing. Qualifications required: An earned doctorate in Industrial or Manufacturing Engineering. At least one or more of the following skills/interests: research interests in modeling and integrating manufacturing environments, training in state of the art processes, knowledge of manufacturing processes that deal with advanced materials, and familiarity with research in aspects of agile manufacturing. Desired qualifications: Special emphasis in electronics manufacturing. Application deadline: February 15, 1994 or 15th of each month until the position is filled. Application procedure: Applicants must send a letter of application, resume, and the names/addresses of three references to Dr. Gerald T. Mackulak, Chair, Faculty Search Committee, Department of I&MSE, College of Engineering & Applied Sciences, Arizona State University, Tempe, AZ 85287-5906. AA/EOE.

Yale University, Electrical Engineering. The Department of Electrical Engineering invites applications for two faculty positions at the Assistant or Term Associate Professorial level in the following areas: (1) Microelectronics/Photonics, including emerging electronic materials, novel electronic devices, and advanced semiconductor device technology; (2) Signals/Communications/Systems, including telecommunications, interactive graphics, imaging science, signal analysis & synthesis, and intelligent systems, with preference given to those research activities which overlap some aspects of computer engineering; and (3) Computer Engineering, with preference given to those research activities closely connected with signal processing, communications, imaging science or intelligent systems. Applicants should have a Ph.D. in Electrical Engineering, Computer Science, Applied Physics, or closely related field, and should exhibit outstanding research accomplishments and a commitment to teaching. Close collaboration with the existing research groups in the aforementioned areas and interaction with the adjacent Department of Computer Science are expected. Preferred candidates are U.S. citizens or have a permanent resident visa. Women and members of minority groups are especially encouraged to apply. Please send curriculum vita, including names, addresses, telephone numbers, and email addresses (if available) of at least three references, to Professor T.P. Ma, Chair, Department of Electrical Engineering, Yale University, 15 Prospect Street, New Haven, CT 06520-8284. Applications are accepted up to March 15, 1994. Yale University is an affirmative action, equal opportunity employer.

Cornell University - Faculty Positions. The Cornell University School of Electrical Engineering has faculty openings at all levels in information technology. We are especially interested in applicants for senior positions. Candidates should have strong commitments to and outstanding achievements in research and teaching. Applicants' research areas should articulate with the National Information Enterprise, broadly construed to include such disciplines as: cable, fiber and wireless communication and computer networks; processing, compression, recognition, interpretation, security, distribution, retrieval and display of data, speech, image, video and multispectral signals; machine vision, machine learning, and architectures for parallel and distributed algorithms; human-machine interfaces with emphasis on handicapped access; broadband switching and high performance computing in support of such applications as interactive TV and HDTV, teleconferencing and telemedicine. Interested persons should submit a letter of application, professional resume, and the names of at least four references to: Director, School of Electrical Engineering, Phillips Hall, Cornell University, Ithaca, NY 14853-5401. Cornell University is an Affirmative Action/Equal Opportunity Employer.

Rutgers University. The Department of Electrical and Computer Engineering anticipates an opening and invites applicants for a tenure-track position at the Assistant Professor level in the areas of circuit design and digital/analog electronics. Ph.D. in EE, or equivalent, and clear potential for distinguished performance in teaching and research is required. The successful candidate's duties will include teaching at the undergraduate and graduate levels, laboratory development, and establishment of scholarly activities in the area of specialization. CAD development, IC testing tools, IC cleanroom fabrication facilities and comprehensive computing facilities currently exist within the department. A resume and the names of four references should be sent to Prof. B. Lalevic, Chair, Electrical and Computer Engineering, Rutgers University, PO Box 909, Piscataway, NJ 08855-0909. Rutgers is an equal opportunity, affirmative action employer.

California State University, Northridge, is accepting applications for Dean, Engineering and Computer Science, available August 1994. The School has 4 departments, 70 full-time faculty, 1,800 undergraduate and 600 graduate students. Undergraduate degrees in both Engineering and Computer Science are accredited. Oversees School programs and resources. With faculty maintains and improves instruction and research. Seeks external support for School. Requires earned doctorate in related discipline, qualification for advanced rank appointment within School, and at least 3 years academic administration experience including resource and personnel management at or above level of department chair. Salary dependent on qualifications. Excellent benefits. Submit letter of application and resume including names of 3 references

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Send me information on joining IEEE *(circle one)* **Regular membership 300** **Student 301**

2 ADDITIONAL COMMENTS

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Void after April 1, 1994 *Void overseas May 1, 1994* **1/94**

names and addresses of five references should be sent to: Dr. Jan Rocek, Chairperson, Search Committee for the Dean of the College of Engineering, Office of Academic Affairs (M/C 105), The University of Illinois at Chicago, 601 South Morgan Street, Chicago, Illinois 60607-7128. (312) 996-9450. The University of Illinois at Chicago is an Affirmative Action/Equal Opportunity Employer.

Announcement of Faculty/Research Positions Available. The Institute for Micromanufacturing (IfM) at Louisiana Tech University is inviting applications from qualified individuals for tenure track faculty, research engineers, research associates, visiting scholars, postdoctors and technician positions in the general areas of Micro Electro Mechanical Systems (MEMS) and micromanufacturing. Specific areas include electroplating and injection molding at the microscale, surface and bulk micromachining, x-ray micromachining, electronic circuit and device miniaturization, and electronic packaging. Appointments for the faculty positions will be considered at the Assistant, Associate and Full Professor rank commensurate with qualifications, which include an earned doctorate in electrical engineering, biomedical engineering, chemical engineering, materials science, physics, biology or a related field, and a strong commitment to education and developing externally funded research. The IfM will be housed in a new 40,000 ft2 facility dedicated to miniaturization technologies. The Institute is currently installing two beamlines/exposure stations at the Center for Advanced Microstructures and Devices for use in x-ray micromachining. The research engineer and associate positions require a minimum of a BS degree and appropriate professional experience in one of the areas mentioned above. Screening of applicants will begin immediately and applications will be accepted until all positions are filled. Please send resume, names of three professional references and a brief description of teaching and research interests to: Chair, IfM Search Committee, Institute for Micromanufacturing, Louisiana Tech University, P.O. Box 10348, Ruston, LA 71272-0046. Louisiana Tech University is an equal opportunity employer. Women and minorities are encouraged to apply.

Electrical Engineering: FAMU/FSU College of Engineering, Tallahassee, FL. Visiting and tenure-track Assistant Professor positions for the 1994-95 academic year. Areas of particular interest are optics/optoelectronics, controls/instrumentation, image/digital signal processing, digital systems, and power. Submit resume and

applications will begin March 1, 1994. The University of Colorado is an Affirmative Action and Equal Opportunity Employer.

University of Virginia. The Department of Electrical Engineering invites applications for a senior level tenured faculty position. Applicants must have an established record of research leadership and prominence in the areas of control theory and sensor based robotics with emphasis on manufacturing. Responsibilities include leading a research group and performing sponsored research, teaching at both undergraduate and graduate levels, and service. An earned doctorate in electrical engineering and a strong commitment to excellence in undergraduate and graduate teaching are required. Established research programs exist in the department already in the areas of control theory, robotics, machine vision, neural networks, computer engineering, solid state electronic and photonic devices, and communications and signal processing. Interested individuals should send a complete resume, statement of present employment and citizenship (or visa) status together with names and addresses of at least four references to: Dr. Robert J. Mattauch, Chairman, Department of Electrical Engineering, Thornton Hall, University of Virginia, Charlottesville, VA 22903-2442. The search will continue until the position is filled. The University of Virginia is an Equal Opportunity/Affirmative Action Employer.

North Carolina State University, Department of Electrical and Computer Engineering. Applications are invited for faculty positions in electrical and computer engineering at all ranks. Qualifications include an outstanding academic record, a doctorate or equivalent in electrical or computer engineering, or a closely related discipline, and a strong commitment to teaching and research. Three faculty positions are expected to be available by January, 1994 and an additional faculty opening may be available by May, 1994. We are especially interested in candidates specializing in: (1) analog and mixed-signal design of microsystems, (2) communications and digital signal processing with applications to multi-media and personal communications systems, (3) design and prototyping of micro sensors including MEMs technology, (4) hardware/software codesign of distributed digital systems and (5) electro-optical technologies and systems. Successful candidates will have the opportunity to work with highly qualified faculty and outstanding students in a range of well-equipped facilities. Please send your resume to Professor R.K. Cavin, III, Department of Electrical and Computer Engi-

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continuing development of the program. In addition, she/he will be expected to develop an active research program. Preference will be given to applicants with industrial or teaching experience as well as to those who will strengthen the department in areas related to electronics, signal processing, and controls, or who would reinforce existing research programs at Tech. Close ties are possible and encouraged with related Ph.D. granting departments including Physics and Computer Science, as well as with organized research activities at Tech such as the Langmuir Laboratory for Atmospheric Research and the National Radio Astronomy Observatory. Collaborations with Los Alamos and Sandia National Laboratories and the White Sands Missile Range are also possible. The starting date is 15 August, 1994. Applications received prior to 15 February, 1994, will be given full consideration; however, applications will continue to be accepted until the position is filled. Send vitae, selected reprints, a letter describing teaching and research interests, and the names, addresses, and telephone numbers of three (3) references to New Mexico Institute of Mining and Technology, Human Resources, Wells Hall, Box C-116, Socorro, NM 87801. AAEOE.

Director, Center for Wireless Communications. The University of Mississippi is now accepting applications for a full time position as Director of the Center for Wireless Communications. Academic appointment will be a tenure track position at the Professor or Associate Professor level, depending upon qualifications. The Center is located in the School of Engineering and has strong industrial sponsorship. The Director will be expected to take a strong interest in research and in teaching wireless/telecommunications. Candidates must have achieved a Ph.D. in Electrical Engineering or closely related field. Candidates should have considerable experience in wireless communications and must be capable of establishing and sustaining long term research and analytical support/services programs with regional and national industrial partners and governmental units. Candidates should have a distinguished record in research and publications and a record of strong participation in professional activities at national level. The graduate program in wireless technology established two years ago has attracted numerous graduate students currently engaged in wireless technology research and the undergraduate program in telecommunications also supports the Center. Applicants should send their resumes to Professor Charles E. Smith, Search Committee Chair, Department of Electri-

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database, parallel processing, p guages and compilers, robotic engineering. Wright State Univ tion of 17,000 students, is locat campus with a significant area o space, in a rapidly growing hig community, and is surroundec and government research ar facilities. A significant portion of graduate students come from The University is proactively cor trial and government partnersh and development ventures. A able, pleasant living environme professionals and their families, venient to the campus. App include a vitae, a brief statemen teaching interests, copies of th representing the candidate's st tions, names of three reference ing recommendations directly Committee, and any additiona porting information. The salar Address applications and suppo to: Chair, Search Committee, Computer Science & Engineer University, Dayton, OH 45435. candidates will begin February tinue on the first of each month or until the position is filled. Wri sity is an equal opportunity/a employer.

Faculty Positions in Comput Engineering & Management applications for tenure-track positions in Computer Science. These positions are at the Assistant or Associate Professor level, dependent upon the qualifications and experience of the candidate. GMI operates on a five-year fully cooperative plan of undergraduate education, offering Bachelor degrees in Applied Mathematics, Electrical Engineering, Industrial Engineering, Management, Manufacturing Systems Engineering, and Mechanical Engineering. GMI is now seeking to offer a degree in Computer Science which will take advantage of our coop program and applied focus. The minimum qualifications for these positions include an earned Ph.D. in Computer Science, experience in and commitment to undergraduate teaching, and effective communication skills in the English language. Experience in industry or in curriculum development is highly desirable. Preference will be given to candidates with expertise in the areas of software engineering, computer networks, operating systems, compilers, and information retrieval. The individuals hired will be expected to participate in curriculum development, teach a variety of courses, continue their research and professional development, interact with colleagues in a multidisciplinary environment, advise students, and participate in service activities. To apply, send resume and names, addresses, and phone numbers of three references to: Dr. Jo Smith, Computer Science Search Committee Chair, Science and Mathematics Department, GMI Engineering & Management Institute, 1700 W. Third Avenue, Flint, Michigan 48504-4898. Review of applicants will commence immediately. To ensure full consideration, applications must be received by February 15, 1994. The appointments will commence July 1, 1994. GMI is an equal opportunity employer; minorities and women are encouraged to apply. Candidates must have proof of legal authority to work in the U.S. GMI is a smoke-free facility.

Santa Clara University, Assistant Professor position in Electrical Engineering. The Department of Electrical Engineering seeks applicants for a tenure track position in electrical circuits and/or networks. Candidates must have a PhD in Electrical Engineering with a research background in electrical circuits and/or networks or a closely related area. Santa Clara University located in Silicon Valley, near San Jose and about 50 miles south of San Francisco. It is a comprehensive university with a particular emphasis on excellence in teaching at the undergraduate level. The Electrical Engineering Department also takes part in a large part-time MS program and has a modest PhD program. The department has 14 full-time faculty mem-

wireless communications and multimedia applications. Applicants are also sought in computer architectures and digital systems, operating systems, software engineering, artificial intelligence, parallel and distributed computing, database management and computer graphics and imaging. Stevens Institute of Technology, founded in 1870, is located in Hoboken, New Jersey on the west bank of the Hudson river directly across from Manhattan, NY. Stevens has recently established an Advanced Telecommunications Institute (ATI), a national center for applied research in telecommunications. The EECS Department offers Bachelor's (programs are accredited by ABET and CSAB), Master's, Engineer's and Ph.D. degrees. Send your vita, with the names of four references, to: Prof. D.R. Vaman, Chairman, Faculty Search Committee, Department of Electrical Engineering and Computer Science, Stevens Institute of Technology, Castle Point on the Hudson, Hoboken, NJ 07030 (dvaman@vaxc.stevens-tech.edu). Stevens is an Affirmative Action/Equal Opportunity employer.

Industrial and Management Systems Engineering. Assistant/Associate tenure-track faculty position for '94-95 A/Y. The individual will be expected to teach and do research in traditional and non-traditional manufacturing processes and systems. This person will support the CIM laboratory and the College thrust for microelectronics manufacturing. Qualifications required: An earned doctorate in Industrial or Manufacturing Engineering. At least one or more of the following skills/interests: research interests in modeling and integrating manufacturing environments, training in state of the art processes, knowledge of manufacturing processes that deal with advanced materials, and familiarity with research in aspects of agile manufacturing. Desired qualifications: Special emphasis in electronics manufacturing. Application deadline: February 15, 1994 or 15th of each month until the position is filled. Application procedure: Applicants must send a letter of application, resume, and the names/addresses of three references to Dr. Gerald T. Mackulak, Chair, Faculty Search Committee, Department of I&MSE, College of Engineering & Applied Sciences, Arizona State University, Tempe, AZ 85287-5906. AA/EOE.

Yale University, Electrical Engineering. The Department of Electrical Engineering invites applications for two faculty positions at the Assistant or Term Associate Professorial level in the following areas: (1) Microelectronics/Photonics, including emerging electronic materials, novel electronic devices, and advanced semiconductor device technology; (2) Signals/Communica-

strued to include such disciplines as: cable, fiber and wireless communication and computer networks; processing, compression, recognition, interpretation, security, distribution, retrieval and display of data, speech, image, video and multispectral signals; machine vision, machine learning, and architectures for parallel and distributed algorithms; human-machine interfaces with emphasis on handicapped access; broadband switching and high performance computing in support of such applications as interactive TV and HDTV, teleconferencing and telemedicine. Interested persons should submit a letter of application, professional resume, and the names of at least four references to: Director, School of Electrical Engineering, Phillips Hall, Cornell University, Ithaca, NY 14853-5401. Cornell University is an Affirmative Action/Equal Opportunity Employer.

Rutgers University. The Department of Electrical and Computer Engineering anticipates an opening and invites applicants for a tenure-track position at the Assistant Professor level in the areas of circuit design and digital/analog electronics. Ph.D. in EE, or equivalent, and clear potential for distinguished performance in teaching and research is required. The successful candidate's duties will include teaching at the undergraduate and graduate levels, laboratory development, and establishment of scholarly activities in the area of specialization. CAD development, IC testing tools, IC cleanroom fabrication facilities and comprehensive computing facilities currently exist within the department. A resume and the names of four references should be sent to Prof. B. Lalevic, Chair, Electrical and Computer Engineering, Rutgers University, PO Box 909, Piscataway, NJ 08855-0909. Rutgers is an equal opportunity, affirmative action employer.

California State University, Northridge, is accepting applications for Dean, Engineering and Computer Science, available August 1994. The School has 4 departments, 70 full-time faculty, 1,800 undergraduate and 600 graduate students. Undergraduate degrees in both Engineering and Computer Science are accredited. Oversees School programs and resources. With faculty maintains and improves instruction and research. Seeks external support for School. Requires earned doctorate in related discipline, qualification for advanced rank appointment within School, and at least 3 years academic administration experience including resource and personnel management at or above level of department chair. Salary dependent on qualifications. Excellent benefits. Submit letter of application and resume including names of 3 references

and 5-year salary history postmarked by February 15, 1994, to: Chair, SECS Search & Screen Committee; Office of Provost; California State University, Northridge; 18111 Nordhoff Street; Northridge, CA 91330-8200. EEO/AA employer encourages applications from women, minorities and persons with disabilities.

Dean of the College of Engineering, University of Illinois at Chicago. The University of Illinois at Chicago (UIC) invites applications and nominations for the position of Dean of the College of Engineering. It is hoped that the appointment will become effective August 1, 1994. UIC, a Research I Institution has 14 colleges, 17,000 undergraduate and 8,000 professional and graduate students and is the largest university in northern Illinois. The College of Engineering has four departments (Chemical Engineering; Civil Engineering, Mechanics, and Metallurgy; Electrical Engineering and Computer Science; and Mechanical Engineering) with over 100 faculty, serving 2,000 undergraduate and about 1,000 masters' and doctoral students. It has an outstanding new Engineering Research building with state-of-the-art research facilities. Candidates for the position must have a demonstrated commitment to academic excellence and diversity, and the ability to further advance the College's standing in research, education, and service, enhance its industrial interactions and stimulate the development of major interdisciplinary research efforts. The position requires administrative experience and demonstrated leadership ability. The candidate's accomplishments must be commensurate with the rank of full professor in one of the College's departments. To ensure fullest consideration, applications should be received by February 15, 1994. Nominations and applications, accompanied by a resume and names and addresses of five references should be sent to: Dr. Jan Rocek, Chairperson, Search Committee for the Dean of the College of Engineering, Office of Academic Affairs (M/C 105), The University of Illinois at Chicago, 601 South Morgan Street, Chicago, Illinois 60607-7128. (312) 996-9450. The University of Illinois at Chicago is an Affirmative Action/Equal Opportunity Employer.

Announcement of Faculty/Research Positions Available. The Institute for Micromanufacturing (IfM) at Louisiana Tech University is inviting applications from qualified individuals for tenure track faculty, research engineers, research associates, visiting scholars, postdoctors and technician positions in the general areas of Micro Electro Mechanical Systems (MEMS) and micromanufacturing. Specific areas include electroplating and injection molding at the microscale, surface and bulk micromachining, x-ray micromachining, electronic circuit and device miniaturization, and electronic packaging. Appointments for the faculty positions will be considered at the Assistant, Associate and Full Professor rank commensurate with qualifications, which include an earned doctorate in electrical engineering, biomedical engineering, chemical engineering, materials science, physics, biology or a related field, and a strong commitment to education and developing externally funded research. The IfM will be housed in a new 40,000 ft2 facility dedicated to miniaturization technologies. The Institute is currently installing two beamlines/exposure stations at the Center for Advanced Microstructures and Devices for use in x-ray micromachining. The research engineer and associate positions require a minimum of a BS degree and appropriate professional experience in one of the areas mentioned above. Screening of applicants will begin immediately and applications will be accepted until all positions are filled. Please send resume, names of three professional references and a brief description of teaching and research interests to: Chair, IfM Search Committee, Institute for Micromanufacturing, Louisiana Tech University, P.O. Box 10348, Ruston, LA 71272-0046. Louisiana Tech University is an equal opportunity employer. Women and minorities are encouraged to apply.

Electrical Engineering: FAMU/FSU College of Engineering, Tallahassee, FL. Visiting and tenure-track Assistant Professor positions for the 1994-95 academic year. Areas of particular interest are optics/optoelectronics, controls/instrumentation, image/digital signal processing, digital systems, and power. Submit resume and names of three references to Faculty Search Committee, Dept. of Electrical Engineering, P.O. Box 2175, Tallahassee, FL 32316-2175 no later than February 15, 1994. Minorities and women are urged to apply. Equal Opportunity Employer.

University of Colorado at Colorado Springs, El Pomar Endowed Chair in Information Integration Engineering. The Department of Electrical & Computer Engineering (ECE) at the University of Colorado at Colorado Springs invites applications for the El Pomar Endowed Chair in Information Integration Engineering. This position will bridge several areas including computer engineering, information theory, signal processing, communications systems and networking, and application-specific device design and fabrication. Areas of specific interest impacted by the chair will include, but are not limited to, high-definition television, measurement instrumentation applications, multi-media applications, image compression applications, group and corporate multi-media applications. The ECE Dept has strong research areas in microelectronics, electromagnetics, communications, signal processing, neural networks, parallel computation, and computer-aided design of VLSI circuits. The Departments of Computer Science and Mathematics have research interests in image processing, software engineering, neural networks, and stochastic processes. The chaired position will creatively bridge between these areas of research strength, provide a focus for joint research projects, and develop linkages with the research and development thrusts of regional and national industry. Earned doctorate degree is required. Send applications to El Pomar Chair Search Committee, University of Colorado at Colorado Springs, ECE Dept., P.O. Box 7150, Colorado Springs, CO 80933-7150. Review of applications will begin March 1, 1994. The University of Colorado is an Affirmative Action and Equal Opportunity Employer.

University of Virginia. The Department of Electrical Engineering invites applications for a senior level tenured faculty position. Applicants must have an established record of research leadership and prominence in the areas of control theory and sensor based robotics with emphasis on manufacturing. Responsibilities include leading a research group and performing sponsored research, teaching at both undergraduate and graduate levels, and service. An earned doctorate in electrical engineering and a strong commitment to excellence in undergraduate and graduate teaching are required. Established research programs exist in the department already in the areas of control theory, robotics, machine vision, neural networks, computer engineering, solid state electronic and photonic devices, and communications and signal processing. Interested individuals should send a complete resume, statement of present employment and citizenship (or visa) status together with names and addresses of at least four references to: Dr. Robert J. Mattauch, Chairman, Department of Electrical Engineering, Thornton Hall, University of Virginia, Charlottesville, VA 22903-2442. The search will continue until the position is filled. The University of Virginia is an Equal Opportunity/Affirmative Action Employer.

North Carolina State University, Department of Electrical and Computer Engineering. Applications are invited for faculty positions in electrical and computer engineering at all ranks. Qualifications include an outstanding academic record, a doctorate or equivalent in electrical or computer engineering, or a closely related discipline, and a strong commitment to teaching and research. Three faculty positions are expected to be available by January, 1994 and an additional faculty opening may be available by May, 1994. We are especially interested in candidates specializing in: (1) analog and mixed-signal design of microsystems, (2) communications and digital signal processing with applications to multi-media and personal communications systems, (3) design and prototyping of micro sensors including MEMs technology, (4) hardware/software codesign of distributed digital systems and (5) electro-optical technologies and systems. Successful candidates will have the opportunity to work with highly qualified faculty and outstanding students in a range of well-equipped facilities. Please send your resume to Professor R.K. Cavin, III, Department of Electrical and Computer Engineering, Box 7911, North Carolina State University, Raleigh, NC 27695-7911. North Carolina State University is an equal-opportunity, affirmative-action employer.

Biomedical Image Processing. The University of Akron invites applications and nominations for a joint appointment, tenure-track assistant professor in the Department of Biomedical Engineering and the Department of Electrical Engineering for the fall semester 1994. The faculty member will be expected to teach both undergraduate and graduate courses in signal and image processing and to carry out research in the areas of biomedical image processing. Send resumes and names, addresses and telephone numbers of three references to: Chairperson, Search Committee, Department of Biomedical Engineering, University of Akron, Akron, OH 44325-0302. Applications will be reviewed monthly until the position is filled. The University of Akron is an Equal Education and Employment Institution.

Electrical Engineering Faculty. New Mexico Institute of Mining and Technology invites applications for a tenure-track position being created (subject to final funding approval) at the Assistant Professor level in the Electrical Engineering department. Exceptional applicants may be considered for a higher level appointment. The department was established in 1989 and offers an ABET-accredited undergraduate EE program, emphasizing small classes and excellence in instruction. Applicants must have a Ph.D. degree in Electrical Engineering (or a closely related field) at the time of appointment. The successful applicant will be expected to excel in teaching undergraduate courses, including laboratory and design classes, and participate in the continuing development of the program. In addition, she/he will be expected to develop an active research program. Preference will be given to applicants with industrial or teaching experience as well as to those who will strengthen the department in areas related to electronics, signal processing, and controls, or who would reinforce existing research programs at Tech. Close ties are possible and encouraged with related Ph.D. granting departments including Physics and Computer Science, as well as with organized research activities at Tech such as the Langmuir Laboratory for Atmospheric Research and the National Radio Astronomy Observatory. Collaborations with Los Alamos and Sandia National Laboratories and the White Sands Missile Range are also possible. The starting date is 15 August, 1994. Applications received prior to 15 February, 1994, will be given full consideration; however, applications will continue to be accepted until the position is filled. Send vitae, selected reprints, a letter describing teaching and research interests, and the names, addresses, and telephone numbers of three (3) references to New Mexico Institute of Mining and Technology, Human Resources, Wells Hall, Box C-116, Socorro, NM 87801. AAEOE.

Director, Center for Wireless Communications. The University of Mississippi is now accepting applications for a full time position as Director of the Center for Wireless Communications. Academic appointment will be a tenure track position at the Professor or Associate Professor level, depending upon qualifications. The Center is located in the School of Engineering and has strong industrial sponsorship. The Director will be expected to take a strong interest in research and in teaching wireless/telecommunications. Candidates must have achieved a Ph.D. in Electrical Engineering or closely related field. Candidates should have considerable experience in wireless communications and must be capable of establishing and sustaining long term research and analytical support/services programs with regional and national industrial partners and governmental units. Candidates should have a distinguished record in research and publications and a record of strong participation in professional activities at national level. The graduate program in wireless technology established two years ago has attracted numerous graduate students currently engaged in wireless technology research and the undergraduate program in telecommunications also supports the Center. Applicants should send their resumes to Professor Charles E. Smith, Search Committee Chair, Department of Electri-

cal Engineering, University of Mississippi, University, MS 38677, by January 31, 1994. The University is prepared to fill this position as soon as possible, but it will remain open until filled. Starting date no later than August 1, 1994. Inquiries can be directed to Professor Smith at (601) 232-7231. The University of Mississippi is an affirmative action/disabled/equal employment opportunity employer. (AA/D/EEOE)

Arizona State University, Electrical Engineering. The Department of Electrical Engineering at Arizona State University is seeking faculty members, potentially in the areas of Power Electronics/Systems, Solid State Electronics (manufacturing emphasis), and Systems and Controls (manufacturing emphasis). Applicants must hold an earned doctorate in Electrical Engineering or a closely related discipline, have a distinguished record of classroom teaching at both undergraduate and graduate levels, have the ability to establish and effectively administer a program of sponsored research and lead and mentor electrical engineers in the early stages of their careers. They should also be prepared to serve the academic community through professional activities. Applicants should show significant evidence of continuing scholarly contributions in addition to the doctoral dissertation. Arizona State University is the fifth largest U.S. university, with approximately 30,000 undergraduates and 12,000 graduate students. The college of Engineering and Applied Sciences at ASU is established among the leading up-and-coming engineering graduate schools. The Department of Engineering has approximately 700 undergraduate and 500 graduate students, and research expenditures of \$3.6M per year. The Department benefits from a strong industrial base within the Phoenix area and active programs in related disciplines within the Centers for Energy Systems Research, Solid State Electronics Research, and System Science Research. Applicants must send a letter of application, a resume with publication list, and the names, addresses and telephone numbers of three references to: Faculty Search Committee Chair, Department of Electrical Engineering, Box 875706, Arizona State University, Tempe, 85287-5706. The first application deadline is February 15, 1994; thereafter, applications will be on the 15th of each month until the positions are filled. Arizona State University is an Equal Opportunity Employer. The Department encourages diversity among its applicants.

Lehigh University. Faculty Position in Computer Engineering. The Department of Electrical Engineering and Computer Science at Lehigh University seeks applicants in applications of computers in manufacturing for a tenure track faculty position. Candidates must have a PhD in computer engineering, computer science or electrical engineering. We require a strong commitment to teaching and evidence of innovative research through appropriate journal publications. Preference will be given to junior faculty, but we would consider senior faculty with an impressive record of publication and funding in the fields of interest. Other areas of research may be considered. The department offers programs in electrical engineering, computer science, and computer engineering leading to a PhD degree. Send e-mail to eecs@eecs.lehigh.edu for further information about the department. Lehigh University is an affirmative action/equal opportunity employer. Women and minorities are encouraged to apply. Candidates are encouraged to respond rapidly by sending a curriculum vita and names of at least three references to Dr. Alastair McAulay, Chair and Chandler Weaver Professor, Faculty Search Committee, Department of Electrical Engineering and Computer Science, Lehigh University, 19 Memorial Drive West, Bethlehem, Pennsylvania 18015.

The Ohio State University, Department of Electrical Engineering, invites applications for a tenure-track position in all areas of Communications. While all levels will be considered, particular emphasis will be given to candidates at the Assistant or Associate Professor levels. Applicants must have a Ph.D. degree in Electrical Engineering or related field, outstanding academic credentials, potential for developing research programs, and an interest in teaching at the undergraduate and graduate levels. Send resume and names and addresses of references to: Professor Yuan F. Zheng, Acting Chairman, Department of Electrical Engineering, The Ohio State University, 2015 Neil Avenue, Columbus, OH 43210-1272. The Ohio State University is an equal opportunity/affirmative action employer.

Carnegie Mellon University. The Department of Materials Science and Engineering has two tenure-track faculty openings at the Assistant, Associate or Full Professor level, for exceptionally qualified persons specialized in one of the following areas: Modeling of materials processing, with emphasis on applying the principles of heat, mass, and fluid flow to solidification, ceramic processing, and/or composite processing. Materials theory, with emphasis on computer simulation/modeling at either the atomistic or continuum scales. Semiconducting materials and devices, dielectrics and passivation, and/or contacts and multi-level metallization. Microstructural development and the mechanical behavior of metals, ceramics composites, or other structural materials. Applicants should have a Ph.D., a demonstrated interest and the ability to develop strong research programs in one of the above areas, and be enthusiastic about teaching at both the graduate and undergraduate levels. Please send resume and names of three references to: Professor David E. Laughlin, Chair, Faculty Search Committee, Department of Materials Science and Engineering, Carnegie Mellon University, Pittsburgh, PA 15213-3890. Phone: (412) 268-2706, Fax: (412) 268-7596. Equal Opportunity/Affirmative Action Employer.

Faculty Position. The Department of Chemical, Bio and Materials Engineering is seeking a junior or senior level Professor for a tenure-track appointment in Bioengineering. The applicant must be qualified to teach basic undergraduate bioengineering courses and graduate level bioengineering specialty courses. The applicant will be expected to direct and mentor graduate students, to maintain an externally sponsored research program, and to participate in the mission of the Center of Neuromechanical Control. Applicants must hold the Ph.D. degree or equivalent in Bioengineering, in another engineering discipline, or in a closely related field. A research specialization in applied motor control, robotics, system theory and control, or powered prosthetic devices is preferred. Applicants must be able to demonstrate direct experience in the field of bioengineering. This position will help establish the Center for Neuromechanical Control which consists of faculty from the Barrow Neurological Institute, the Department of Electrical Engineering, and the Bioengineering Program working synergistically to develop prosthetic devices controlled by neuronal signals. The Bioengineering Program within the department consists of seven full-time faculty and has an enrollment of 160 undergraduate and 55 graduate students. Degrees conferred by the department include the B.S., M.S., and Ph.D. degrees in Bioengineering. Joint research projects with local medical research institutions are encouraged, and currently include projects funded by the NIH, NSF, The Whitaker Foundation, and American Heart Association. Address applications and correspondence to: Gary T. Yamaguchi, Ph.D., Chair of the Search Committee, Department of Chemical, Bio and Materials Engineering, College of Engineering and Applied Sciences, Arizona State University, Tempe, Arizona 85287-6006. e-mail:yamaguch@asuvax.eas.asu.edu Candidates must supply a curriculum vitae, a letter stating teaching and research interests, and names, addresses, and phone numbers of at least three references. Questions and inquiries may be submitted by e-mail, but applications and nominations must be received by post. The search committee will begin to review applications on February 15, 1994. Applications received after that date will be reviewed on a biweekly cycle, as necessary, until the position is filled. The preferred starting date is August 16, 1994, but the date is negotiable. Arizona State University, an equal opportunity, affirmative action employer.

Boston University. The Department of Electrical, Computer and Systems Engineering at Boston University seeks applications for anticipated faculty positions in the areas of photonics, communication networks, and signal/speech/image processing. All positions are for tenure track or tenured appointments starting in September 1994. An earned PhD in a relevant discipline is required. Faculty are expected to develop a program of funded research in their area of expertise. Boston University is located in the heart of the Boston academic community along the Charles River, with easy access to the outstanding scientific, cultural and tourist attractions of the city. The Department has 30 faculty and approximately 50 PhD, 200 MSc and 400 BSc majors. Opportunities exist for collaboration with other colleagues in the Boston area, as well as with the many electronics and software companies in the area. Applicants should send their curriculum vita to Professor Thomas G. Kincaid, Chairman, Department of Electrical, Computer and Systems Engineering, Boston University College of Engineering, 44 Cummington Street, Boston, MA 02215. Boston University is an Equal Opportunity/Affirmative Action Employer.

Position in Electrical Engineering at Alfred University. Full time tenure track position, Division of Electrical Engineering, Alfred University, Ph.D. in EE or related field, teaching experience, scholarly activity, good communication skills, ability to motivate students a must. Industrial experience, P.E. desirable. Strong background in EM fields, software engineering desired, other fields considered. Position open July 94. Review of applications will begin Jan. 15, and continue until position filled. Send application, resume, 3 letters of recommendation to Dr. J.T. Lancaster, EED, Alfred University, 26 No. Main Street, Alfred, NY 14802-1232, or Fax to (607) 871-2348. Tel (607) 871-2130. Alfred Univ is an AA/EOE.

Arizona State University, Chair of Chemical, Bio & Materials Engineering. Arizona State University (ASU) invites nominations and applications for the position of Chair of the Department of Chemical, Bio and Materials Engineering (CBME) in the College of Engineering and Applied Sciences. The CBME department consists of twenty-seven faculty, and offers B.S., M.S. and Ph.D degrees in Chemical Engineering, Bio Engineering, and Materials Science. The departmental enrollment includes 440 undergraduates, 95 Masters students and 55 Ph.D. students. Annual research expenditures are at a level of \$ 2.5m. Opportunities exist for developing synergistic research programs that combine expertise between traditional Chemical, Bio and Material Engineering disciplines. The research interests of the faculty include semiconductor processing and characterization, environmental technology, bioprocessing and process control, advanced alloy systems, neuromotor control, biosensors and biomaterials. ASU is a multicampus university widely recognized as one of the most rapidly emerging major research institutions in the U.S. Its main campus is located near the heart of metropolitan Phoenix in the city of Tempe. Phoenix is a cosmopolitan, culturally diverse area of approximately two million people. The College of Engineering & Applied Sciences has 11 academic departments and schools and eight research centers. The enrollment in the college includes 4,405 undergraduates and 2,252 graduate students (396 Ph.D.'s) with 220 tenured or tenure-track faculty members. The College has been recognized for its innovative Engineering Excellence Program, a three-way partnership between state government, industry, and the university. The Chair reports to the Dean of the College of Engineering and Applied Sciences, provides intellectual leadership to the department, promotes the development of a shared vision of academic excellence, facilitates cross-disciplinary interactions and represents the department to the academic community at large. The Chair takes an active role in faculty development, and works with faculty across the department to encourage innovation in teaching and aggressively pursue a wide range of research opportunities. The Chair promotes cultural diversity and minority development throughout the Department. Candidates must have an

earned doctorate in any area closely related to Chemical, Bio or Materials Engineering, and must be qualified for a tenured full professorship in the department. Candidates must have a strong record of scholarly achievements and must provide evidence of strong leadership, management and interpersonal skills. Candidates must supply curriculum vitae, a letter of interest, and names, addresses and phone/fax numbers of at least five references to Professor H.J.S. Fernando, Chair, Search Committee for the Chair in CBME, Box 876106, Arizona State University, Tempe, AZ 85287-6106. Questions regarding this position may be directed by e-mail to J.Fernando@asu.edu. The deadline for the applications is March 1, 1994, or the first of each month thereafter until the position is filled. The position is tenable after July 1, 1994, or as soon as possible thereafter. Salary is competitive. Arizona State University is an Equal Opportunity, Affirmative Action Employer.

Computer Science Position: (Computer Software). The University of Wisconsin-Parkside, Department of Computer Science and Engineering, invites applications for a tenure-track faculty position beginning in September 1994. The position is at the assistant professor level, but higher rank is possible for an outstanding candidate. Candidates should have a doctorate in computer science, computer engineering, or a related field with strong commitment to undergraduate teaching for a diverse student body, and to scholarly activity - preferably involving undergraduate students and/or regional business and industry. Primary need is in the areas of software engineering, distributed systems, object oriented programming, and operator/human interfaces, but all qualified candidates will be considered. Current faculty interests are in systems software, artificial intelligence, computer graphics, and real-time applications. The University of Wisconsin-Parkside is one of 13 degree-granting campuses of the University of Wisconsin System. The campus is located on a beautiful site near Lake Michigan within the Chicago-Milwaukee industrial corridor. Applicants should send a resume, a statement concerning teaching and research interests, and a list of at least three references to: Dr. George Perdikaris, Chairman, Department of Computer Science and Engineering, University of Wisconsin-Parkside, 900 Wood Road, Kenosha, WI 53141-2000. Closing date for applications is February 7, 1994. UW-Parkside is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply.

Boston University. Postdoctoral position in dynamics of artificial neural networks. Applicants should send their curriculum vita and the names of three references to Professor Thomas G. Kincaid, Chairman, Department of Electrical, Computer and Systems Engineering, Boston University College of Engineering, 44 Cummington St., Boston, MA 02215. Boston University is an Equal Opportunity/Affirmative Action Employer.

Chair, Department of Electrical Engineering Technology, Indiana University Purdue University Indianapolis (IUPUI). Applications and nominations are invited for the position of Chair, Department of Electrical Engineering Technology, of the Purdue School of Engineering and Technology at IUPUI, available July 1, 1994. Responsibilities of the position include administration of the academic program and budget, faculty recruitment and development, student advising, working with industry and advisory committees, leadership in generating external funding, long-range strategic planning, student recruitment and teaching (up to 6 credit hours per semester). The candidate should have good communication skills, administrative experience, a distinctive record of university teaching, and professional achievement or equivalent industrial experience suitable for appointment at the rank of full professor. The candidate shall have significant industrial experience and demonstrated ability to communicate effectively with academia and industry. A master's or Ph.D. degree in a closely related technical field and expertise in one of the department's specialties is required. Professional engineering registration is preferred. Candidates from industry, engineering, and engineering technology programs are encouraged to apply. Applicants should submit C.V., a statement of academic accomplishments and objectives, and the names of five references. Materials should be submitted by February 15, 1994, to Professor Roy E. Westcott, Chair, EET Search Committee, Indiana University Purdue University Indianapolis, 799 W. Michigan Street, Indianapolis, IN 46202. Applications will be accepted until the appointment is made. The Department of Electrical Engineering Technology has 350 majors and offers ABET-accredited programs in electrical engineering technology at the associate and baccalaureate level. The Department also offers an associate degree in biomedical electronics technology. With 2,300 students, the School of Engineering and Technology is one of the largest of 18 academic units at IUPUI. IUPUI is a comprehensive urban campus that enrolls more than 28,000 students and offers 174 academic programs. IUPUI is an Equal Opportunity, Affirmative Action employer. Women and minority candidates are encouraged to apply.

Chair, Department of Electrical Engineering, Indiana University Purdue University Indianapolis (IUPUI). Applications and nominations are invited for the position of Chair of the Department of Electrical Engineering of the Purdue School of Engineering and Technology at IUPUI, available July 1, 1994. It is preferred that the individual hold credentials and qualifications to be eligible to hold a tenured full-professorship in the School. Candidates should have a Ph.D. in electrical engineering or a related area. They should have demonstrated the ability to provide leadership for a department with undergraduate and graduate programs, to be innovative and effective in teaching, to conduct vigorous, pioneering research, and to have excellent communication skills. Consideration will be given to a candidate's skills in attracting external sponsorship and building collaboration among a diverse community of academe, industry, and government. Applicants should submit C.V., a statement of academic accomplishments and objectives, and the names of five references that the search committee may contact. Materials should be submitted by February 15, 1994, to Professor Clifford E. Dykstra, Chair, EE Search Committee, Indiana University Purdue University Indianapolis, SL 2150, 723 West Michigan Street, Indianapolis, IN 46202. Applications will be accepted until the appointment is made. Current research and teaching interests in the department include circuits and electronics, communications and signal processing, controls and robotics, digital and VLSI design, and biomedical engineering. The department enrolls over 300 undergraduate majors and 40 graduate students. With 2,300 students, the School of Engineering and Technology is one of the largest of 18 academic units at IUPUI. IUPUI is a comprehensive urban campus that enrolls more than 28,000 students and offers 174 academic programs. School resources include the Electronics Manufacturing Productivity Facility (EMPF), sponsored by the Naval Material Command and IUPUI and designated a National Center for Excellence. The EMPF works in collaboration with industry, the Navy, and IUPUI faculty to bring manufacturing technology into the engineering environment. IUPUI is an Equal Opportunity, Affirmative Action employer. Women and minority candidates are encouraged to apply.

The University of California at Berkeley invites applications for tenure-track positions in Electrical Engineering and Computer Sciences, at the Assistant Professor level, beginning in Fall Semester 1994, pending budgetary approval. Applicants should have received (or be about to receive) a doctoral degree in Computer Science or Electrical Engineering or a closely related field. All areas of research in Computer Science and Electrical Engineering will be considered. Successful applicants will be expected to set up a quality research program and to teach both graduate and undergraduate courses in their general area of specialty. As such, the principal requirements of this position are excellence in research, teaching, and academic leadership. Interested persons should send a resume, a select subset of papers, and the names and addresses of three or more references, by February 28, 1994, to the appropriate address below. In addition, the applicant should ask three references to send letters directly to the same address. Applications submitted after the deadline will not be considered. Electrical Engineering Applications: Professor David Messerschmitt, Chair, Department of Electrical Engineering and Computer Sciences, 231 Cory Hall, University of California, Berkeley, California 94720. Computer Science Applications: Professor Robert Wilensky, Associate Chair Computer Science Division, 581 Evans Hall, University of California, Berkeley, CA 94720. The University of California is an Equal Opportunity, Affirmative Action Employer.

Colorado School of Mines, Golden, Colorado. Faculty Position in Engineering, Electrical Engineering, Digital Imaging. The Colorado School of Mines is accepting applications for a tenure track faculty position in the Division of Engineering. This Division offers interdisciplinary degree programs in engineering and is oriented toward interdisciplinary engineering research as it relates to the energy, materials and resource industries. Candidates for this position must have a strong background in electrical engineering with hardware oriented research credentials and expertise in contemporary image acquisition technology, coupled with experience in image-processing in a Unix environment. Further preference will be given to candidates having applications interests in any or several of the following areas: advanced materials diagnostics, non-destructive evaluation techniques, machine vision, flow visualization, and computed imaging. Responsibilities include the development of a funded research program in digital imaging with interdisciplinary applications in energy or materials, teaching at the graduate level in engineering, teaching at the undergraduate level in lower and upper division electrical engineering, and innovation and program development in interdisciplinary engineering education. Candidates must have a doctoral degree in electrical engineering or related area, including at least a baccalaureate degree in electrical engineering, and should have a clear commitment to excellence in engineering education. Preference will be given to candidates who have an established record of scholarly accomplishments, funded research, and teaching excellence. Application deadline: 15 February, 1994, or until such time as a successful candidate has been identified. The application package must include a resume, the names and addresses of three references, and supporting materials which must include a one page statement on professional compatibility with the needs of this position. Applications should be directed to: Colorado School of Mines, Digital Imaging Search #92-10-27, 1500 Illinois Street, Golden, CO 80401. An equal opportunity/affirmative action employer.

The Department of Electrical and Computer Engineering at the University of Missouri-Columbia's Kansas City (CEP) program invites applications for a tenure track position in Electrical and Computer Engineering at the Assistant, Associate or Full Professor level. Faculty in the CEP are University of Missouri-Columbia faculty that reside in the Kansas City area. The CEP is a full-time teaching and research program with 17 faculty members offering ABET accredited B.S. degrees as well as Masters and Ph.D. degrees in Electrical, Mechanical and Civil Engineering. The CEP Electrical Engineering program presently has 130 undergraduates, 50 graduate students pursuing Masters and Ph.D. degrees, and an active research program in computers, electromagnetic fields, electro-optics, and power. Applicants must have earned Ph.D. in electrical engineering, and a proven record of scholarly work in both teaching and research. Responsibilities include teaching engineering courses at all levels (B.S. through Ph.D.), establishing high quality programs in sponsored research, research collaboration with local industry, supervising Master's and Doctoral students, and advising students at all levels. Preference will be given to candidates with prior experience at other engineering institutions or significant industrial research experience in computer engineering or power. Desirable candidates should have either U.S. citizenship or a permanent residency. Applicants should send a resume, a statement of research and teaching interests, and three references to Dr. Jerome Knopp, Electrical and Computer Engineering Department, University of Missouri-Kansas City, 5100 Rockhill Road, Kansas City, Missouri 64110. Candidates are sought for the semester starting September 1994. All applications received by March 12, 1994 will be considered, and later applications will be considered

until the position is filled. The University of Missouri is an equal opportunity, affirmative action employer.

The Australian National University, Research School of Information Sciences and Engineering, Fellow/Senior Fellow in Telecommunications Engineering (Level C/Level D). Applications are invited for a tenurable position in research and postgraduate training at academic level C or D in a new telecommunications Engineering Group in the Research School of Information Sciences and Engineering. The emphasis in the School is on excellence in research at a fundamental level, quality supervision of PhD students and industrial and other outside interactions. The successful applicant should already have an international reputation in the postdoctoral career phase but with reputation still developing rapidly, and with a career objective and identifiable potential of becoming an IEEE Fellow. Leadership skills are clearly important. The new group would be expected to collaborate in other activities in the School, in joint research projects, student supervision, provision of course material, and participation in one or more of the Cooperative Research Centres associated with the School, viz CRC for Robust and Adaptive Systems, CRC for advanced Computational Systems and Research Data Network CRC. Collaboration in activities in the Faculty of Engineering and Information Technology would be welcome. Systems aspects of telecommunications, as opposed to device/physics aspects will be preferred. Typical research outlets would include IEEE Transactions on Communications and possibly IEEE Transactions on Information Theory. It is probable that, in view of the joint appointment with Computer Sciences Laboratory, some activities of the group, but not necessarily the appointee, would fall in this networks area. Contact: For further information about the position, please contact the School's Acting Director, Professor Brian Anderson (61-6) 249 5127, Fax (61-6) 249 2698. Further particulars, which include the selection criteria, are available from the School Secretary, telephone (61-6) 249 5185; Fax (61-6) 249 1884; email sec050@rsphysse.anu.edu.au. Closing date: 28 January 1994. Reference ISI 17.11.1. Salary: Fellow - AUS$50,225 - AUS$57,913 p.a. Senior Fellow - AUS$57,913 - AUS$68,618 p.a. A market-related salary loading may be paid in appropriate instances. Appointment: The appointee will be appointed head of the group, initially for an agreed period of between three and five years. Applications addressing the selection criteria should be submitted in duplicate to the Secretary, The Australian National University, Canberra, ACT 0200, Australia, quoting reference number and including curriculum vitae, list of publications and names and addresses of six referees. The University has a "no smoking" policy in all University buildings and vehicles. The University is an equal opportunity employer.

Research Staff positions available in Department of Electrical Engineering at Princeton University to conduct research in electronic materials, computer engineering or information science and systems. Most staff devote time principally to research, with some opportunities for teaching and thesis supervision when appropriate. A doctorate is required. Respond to Ms. Carol Desmond, Department Manager, Dept. of EE B204 E-Quad, Princeton University, Princeton, NJ 08544. Princeton University is an Equal Opportunity/Affirmative Action Employer.

E.A. "Larry" Drummond Chair of Computer Engineering. The University of Alabama invites nominations and applications for the E.A. "Larry" Drummond Chair of Computer Engineering. The successful applicant must have a distinguished research and publication record, a strong commitment to engineering education, and a demonstrated ability to provide leadership in developing and expanding research and academic programs in computer engineering. He or she must develop a funded program and more importantly provide a focus to assist other faculty in developing research programs in Computer Engineering. The position requires an earned Ph.D. in Electrical or Computer Engineering or in a closely related field. U.S. citizenship or permanent residency is required for a tenure track appointment. Salary will be commensurate with qualifications. Submit nominations and applications to Dr. Russell Pimmel, Department of Electrical Engineering, University of Alabama, Box 870286, Tuscaloosa, AL 35487-0286. The Search Committee will begin reviewing applications March 1, 1994 and will continue until the position is filled. Female and minority candidates are strongly encouraged to apply. The University of Alabama is an Equal Opportunity Affirmative Action Employer.

Research Scientist/Visiting Professor. The Space Vacuum Epitaxy Center at the University of Houston invites applications for a Research Scientist/Visiting Professor position with appointment starting January 1994. We are seeking candidates with a Ph.D. in Physics, Electrical Engineering, or a related field to join our expanding program in optoelectronic device research. Research expertise and interest in III-V quantum well devices, monolithically integrated optoelectronic devices, and in situ processing are helpful. The center is equipped with Class 10 and Class 100 clean rooms and MBE/CBE capabilities. The salary of the appointment will be commensurate with qualifications and experience. Applicants should send a curriculum vitae, a list of publications, and three letters of recommendations to: Dr. A. Ignatiev, Space Vacuum Epitaxy Center, University of Houston, Houston, TX 77204-5507. Review of applications will begin immediately until the position is filled. The University of Houston is an EEO/AA employer. Minorities and women are encouraged to apply.

Electrical Engineering Technology: The Pennsylvania State University at Erie, The Behrend College. Applications are invited for a faculty position at the instructor or assistant professor level to teach associate and baccalaureate level technology courses starting Fall 1994. Preference will be given to candidates with an emphasis in factory automation, microprocessors, motors, data acquisition and process control. M.S. in electrical engineering or equivalent with a minimum of six years industrial experience required, professional registration preferred. Penn State Behrend is a 4-year primarily undergraduate institution within the 22-campus Penn State system. Behrend's technology programs are growing and have the support of local industry. Application deadline is February 15, 1994 or until the position is filled. Send complete resume, official transcripts and the names of three references to Dr. R. Progelhof, Director, School of Engineering and Engineering Technology, Dept. EET 1, The Pennsylvania State University, Erie, PA 16563-0203. An equal opportunity/affirmative action employer. Women and minorities encouraged to apply.

The School of Information Sciences and Technology at Monmouth College invites applications for two tenure-track positions in Software Engineering at the Associate or Full Professor level commencing September 1994. The Software Engineering Program is a professionally oriented Master's program and is designed to integrate elements of computer science, management science, human factors, engineering, and computer communications technology into systematic methods for developing reliable and effective computer software systems. Candidates are sought who are interested and capable in both teaching several of the six core courses in the program as well as advanced courses in an area of specialization and in participating in funded research projects. A Ph.D. in some related discipline is required. A complete position description is available upon request. Applicants should submit resume to: Dr. Richard A. Kuntz, Dean, School of Information Sciences and Technology, Monmouth College, West Long Branch, NJ 07764. The closing date is February 1, 1994. Monmouth College is an equal opportunity/affirmative action employer.

Government/Industry Positions Open

Engineer I: Hardware and software design and testing of embedded computer systems with applications in automobile power train controllers. Preparing written technical reports. Job requires minimum of Bachelor's Degree in Electrical Engineering. Required minimum of 4 credit hours each in Computer Architecture and Digital Circuit Design. Minimum of 3 credit hours of Embedded System Design and Applications Lab. Minimum of 4 credit hours of VLSI or equivalent course. University level technical writing class of 3 credit hours. 40 hr/wk, 8:30 a.m. - 5:00 p.m.; $20 per hour-$30 per hour OT. Send resumes to 7310 Woodward Avenue, Room 415, Detroit, MI 48202. Reference Number 71393. "Employer Paid Ad."

Electrical Engineer P.E. for Florida Consulting Firm. Commercial/Hospital experience a must. Partnership potential. Write: Emtec Corporation, 250 Bird Road, Suite 200, Coral Gables, FL 33146. Fax: (305) 461-3390

Software Design Engineer; By February 1, 1994; Please send resume to: Employment Security Department, E&T Division, Job # 399312-T, P.O. Box 9046, Olympia, WA 98507-9046. Job Description: Designs, implements, and tests software for micro computers following standard procedures. Redesigns advanced printing system software, including graphics rendering, low level input/output, and communications software, to facilitate portability and ports software to different printers and printer controllers, utilizing MS-DOS operating system, and "C", 86 Assembler Series, and other assembly languages. Requirements: Master's degree in Electrical Engineering, Computer Science, Mathematics or Physics; 6 months of work or minimum of semester long or equivalent school thesis project experience in programming or computer software design utilizing MS-DOS operating system, "C", 86 Assembler Series, and one other assembly language; and design and implementation of graphics rendering software, and low level printer communication software, and porting printer software to different controllers. Experience may be gained concurrently. Must Have Legal Authority To Work In The United States. Job Location: Seattle Area Employer. Salary: $40,500-$49,500 per annum, depending on experience. Compensation package includes bonuses and stock options. 40 hours per week, flex time. EOE.

Help Wanted: Power Systems Engineer by January 30, 1994, please send resume to: Employment Security Department, E&T Division, Attn: Job # 401886, P.O. Box 9046, Olympia, Washington 98507-9046. Job Description: Power Systems Engineer for the EMS Generation/DTS Team within the Technology Group. Design, develop and test software products. Work to develop Power Systems Applications using expert system technology, including network analysis, generation and dispatcher training simulator. Design and develop on-line transient stability analysis and transient energy function analysis software to implement on-line dynamic security assessments. Requirements: Master's degree in Electrical Engineering, Computer Science or Mathematics; To include 20 course hours in Power Systems Engineering; 1 year experience in power systems programming; 6 months experience in transient stability software design and 3 course hours or 3 months experience in expert systems; 6 months experience or ten course credits in VAX/VMS and UNIX operating systems and Fortran and "C" languages. (All experience may be gained concurrently.) Must Have Proof of Legal Authority to Work in the United States. Salary Range: $41,500 - $51,817 per year. 40 hours per week, 8 a.m. to 5 p.m., M-F. Position in Bellevue, Washington. EOE.

Paradigm Shift, Inc. is seeking a candidate for the position of Software Engineer/Trainer. The ideal candidate will meet or exceed the following requirements: Ph.D. in Software Engineering or equivalent, 10 years experience in industrial systems software and development, 3 years experience in OOP, demonstrated excellence in teaching, willingness to travel minimum 30 weeks per year. The job responsibilities include: Train clients in OOP, OOD, and OOA to provide optimal technology transfer to the OO paradigm. Provide consulting which guides client's process and architectural and design decisions, develop training material, develop C++ software compo-

nents. Compensation will be base salary plus bonus for each week traveled. Total starting range $75,000 - $115,000 plus generous benefit package. Relocation to the corporate location is not required at this time. Applicants should contact John Meyers, Product Manager, at Paradigm Shift, Inc., P.O. Box 5108, Potsdam, NY 13676, Fax 315-353-6110, meyers@parashift.com

Research Scientist to design/develop fiber-optic interferometric spectrometers, integrated optical sensors, tactile arrays, phase sensitive fluorometers for environmental/industrial applications. Laboratory exp. in single-mode fibers, molecular self-assembly multilayer and sol-gel deposition, liquid-crystal waveguides. Working knowledge of phase-conjugate resonators, non-linear optics, iterative image processing. Req: Ph.D. Phys./EE +2 yrs. exp. 40 hrs/wk, $18/hr. Job site: Radford, VA. Mail resume & copy of Ad to VEC, VA3111061, POB 61, Roanake, VA 24002-0061.

Cellular Telecommunications Engineering Manager: Direct radio engineering group of cellular telecommunications firm in designing networks to enhance capacity; developing standards for new products and services; expanding service clusters; improving the dependability of service; implementing digital technology; evaluating radio technologies; providing technical support to field operations; and managing the radio aspects of the relationships with key system suppliers. Requirements: B.S.E.E. 2 yrs. exp. directing the activities of licensed professional electrical engineers as Manager of Radio Engineering for cellular telecommunications firm with multiple markets and at least 200,000 customers; 4 yrs. exp. designing radio cellular AMPS systems with Ericsson CMS 8800 architecture; 2 yrs. exp. preparing technical and engineering documentation for cellular license applications in jurisdictions utilizing the Global System Mobile standards; 2 yrs. exp. designing 900 MHz mobile data and paging systems. (Experience may be gained concurrently.) Must Have Legal Authority To Work In The United States. Job Location: Kirkland, Washington. Salary: $70,000 per annum; Compensation package incl. stock option and bonus. 40+ hours per week, 9-5. By January 31, 1994, send this ad and resume to: Employment Security Department, E&T Div, Job No. 396462, Olympia, WA 98507-9046.

Engineering, Software: Serve as Architect & Senior Designer of software driver for next generation of graphics controller supporting motion video & audio applications on a Personal Computer; responsible for coordination & technical leadership of engineering team split across geographic locations. M.S. degree in Computer Science, or Mathematics, or Mathematical Logic and Theory. 5 years experience as a Software Engineer. Software engineering experience must include: Digital Video (DVI®) development; application of DVI technology in Action Media II environment; graphics as well as integrated graphics and motion video adapter hardware architecture; operating system design & implementation, including multimedia extensions; experience in running a multisite engineering development team. $66,240/yr.; 40 hrs./wk. Place of employment and interview: Hillsboro, OR. If offered employment, must show legal right to work. Send this ad and your resume to: Job Order #5550580, 875 Union Street, N.E., Room #201, Salem, OR 97311. The company is an equal opportunity employer and fully supports affirmative action practices.

Power Engineer - Provide technical support services to system control center to update, develop and maintain electric utility's energy management system and other control center automation systems. Provide support in the areas of (1) the energy analysis applications, (2) the power network application which includes the state estimation, contingency analysis, and load flow analysis. Apply artificial intelligence in the area of power systems restoration. Duties involve an interface of responsibilities in the area of power systems of the electrical engineering and computer areas. Require MSEE and 6 months experience as Power Engineer Intern. Education and master's thesis must be in area of power systems. Education must include courses in each of the following: Energy Conversion, Computer Analysis of Power Systems, Industrial Power System, Computer Simulation of Power System Components and two courses in Power System Analysis. Familiarity with Control Power Systems and Industrial Drives. Education or experience must include extensive use of FORTRAN, BASIC, C, assembler language, VAX/VMS, VAX/UNIX, MS-DOS, Word Processing and spread sheet programs, and IBM-PC or compatible. 40 hrs/wk 8 a.m. to 5 p.m. $35,400/yr. Send resume with social security number to Indiana Department of Workforce Development, 10 N. Senate Avenue, Indianapolis, IN 46204, Attn: Gene R. Replogle. Refer to I.D. #3288609.

Project Engineer wanted for vehicle's electrical and electronic system design and modeling simulation; simulation of electrical magnetic interference and electro-magnetic compatibility projects in automobile industry which will include simulating electrical circuits using SPICE, SABER and ORCAD, simulating optical systems for pattern recognition using MATLAB and electrical hardware and software simulation; Reqs. Master's in Elec. Engg., 2 yrs exp. in job offered or 2 yrs. related exp. as Project Engineer. 2 yrs. of the related exp. must have included electrical hardware and software development. Related exp. or Master's thesis research must have included simulating electrical circuits using SPICE, SABER and ORCAD software, programming using C language; and 1 univ. course in Theory of Optical Waveguides, Contemporary Optics, Optical Information Processing, Fiber & Integrated Optics, Electrodynamics, and Antenna; $3,317.40/mo., 40 hrs/wk. Send resume to 7310 Woodward Ave., Room 415, Detroit, MI 48202. Ref. #84493 "Employer Paid Ad"

Scientist, Research: Research on new CAD tool for auto verif of VLSI circ (formal verif, logic simul, timing verif & test); devel prototype CAD tool to demo "proof-of-concept"; solve problem relevant to high custom design envrnmt. PHD in EE or Comp Sci; or MS in EE or Comp Sci + 2 yrs exp in VLSI CAD R&D reqd. $7000/mo. 40hr/wk. Exp w/ VLSI CAD algorithm research (formal verif, logic simul, timing verif, logic synthesis), implicit technq for Boolean manipulations on circ, & delay test method devel reqd. Knlg of large s/w sys devel in C/C++ in Unix reqd. Job site/intrv: Berkeley, CA. Send ad & resume to IEEE Spectrum, Box 1-1, 345 East 47th Street, New York, NY 10017.

Software Applications Engineer for NE Ohio software development company, to design & develop object-oriented software & graphical user interface using XLib programming, Motif, Athena & Open Look libraries; conduct studies to determine functional & performance requirements; prepare product specifications; develop user interface for distributed discrete event simulator in C, Motif under X Window system of UNIX operating systems: design & conduct tests for quality assurance of product; document, maintain & upgrade software. Applicants will qualify with 3 months exp. in above duties or 3 months exp. as a System Analyst (exp. must be with X Window system of UNIX operating systems and design & development of programs in C language) and an M.S. in Electrical Engineering or Computer Science (Master's thesis must have been in design development of object-oriented software and graphical user interface using XLib programming, Motif, Athena & Open Look libraries). Must have proof of legal authority to work permanently in U.S. M - F, 8:AM - 5:PM, $37,000/yr. Please send resume, copies of degrees, transcripts and letters confirming the required experience in duplicate (No Calls) to J. Davies, JO# 1402608, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, OH 43216.

Electrical Engineer needed to design control panels and automation systems; estimation of job cost; follow-up with field installation and close out costing; use autocad and computers. BSEE degree required. 2 courses in control systems; 2 courses in Protective Relays; 2 courses in electrical energy systems engineering. 40 hrs/wk. $15.68/hr. 7:00 a.m. - 3:30 p.m. Send Resumes to 7310 Woodward Ave., Rm. 415, Detroit, MI 48202. Ref. No. 88293. Employer Paid Ad.

DSP Development Engineers Needed! Must have DSP microprocessor firmware dev't skills, TMS320 and TMS32OC25 is a big asset. 3 yrs. experience min. Toronto location. Fax CV to ISG (905) 602-6091.

Government/Industry Positions Wanted

EE PhD candidate, Rensselaer Polytechnic Inst., seeks employment for summer (May-Aug) 1994 in Europe/Australia. Experienced in Signal Processing, Communications, Computers, Controls and Biomedical eng. Excellent communication/interpersonal skills. Speaks German, Spanish & French. Resume available in Postscript (chugani.ps.Z) & ASCII (chugani.asc.Z) compressed formats via anonymous FTP from ftp.rpi.edu (128.113.1.5) in /pub/misc. Phone: (518) 271-0156, Email: chugani@ecse.rpi.edu, Address: 2246 14th Street, Troy, NY 12180, USA.

THE UNIVERSITY OF TROMSO

TWO VACANT PROFESSORATES

in Electrical Engineering at the Institute of Mathematical and Physical Sciences. Required background: signal analysis, image processing, electronics, measurement or control techniques. If fully qualified applicants are not available, appointments may be made to temporary positions for up to three years. The annual salary of a fully qualified professor is at present NOK 307.524 - 345.548 depending on qualifications. There will be a deduction of NOK 6.029 - 6.283 per annum to be paid into the compulsory pension fund. Further information may be obtained from: Lasse Lønnum, Chief Administrator, tel. 011.47.77 64 40 03, e-mail: lasse@adm-imr.uit.no or Truls Lynne Hansen, Head of Department, tel.011.47.77 64 51 46.

DEADLINE FOR APPLICATIONS: 26. JAN. 94.

Applications should be sent in 5 copies together with the relevant certificates to:

THE UNIVERSITY OF TROMSØ
N-9037 Tromsø, Norway.

Full directives for application and job description can be obtained at the abovementioned address.
Telefax: 011.47.77 64 49 00.

Cicero Boda

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Scanning
The Institute

Send for the IEEE's strategic plan via e-mail

Adopted by the Board of Directors at its November meeting in Raleigh, N.C., the strategic plan setting the IEEE on course for the 21st century can be transmitted to members as an ASCII file by electronic mail, ftp, or Gopher. The plan calls on the IEEE to promote "the development of electrotechnology and allied sciences, the application of those technologies for the benefit of humanity, the advancement of the profession, and the well-being of its members."

To receive the document via electronic mail, send a message to "fileserver@info.ieee.org". No subject is required, but if your mail software requires one, type any character in the subject field. In the body of the message, put the file name you wish to receive: "strategic.plan". The file server will automatically send it.

To use anonymous ftp, set your ftp software to point to "ftp.ieee.org". Then log on as "anonymous". Make your e-mail address the password, change the directory to info/corp, and get "strategic.plan".

To use Gopher software, set it to point to "gopher.ieee.org". Then look under IEEE information files, Corporate Services Information, and get the strategic plan.

Reporters needed

Got a nose for news? THE INSTITUTE, the IEEE's newspaper for members, is going to change and members everywhere are being asked to play a role. If you'd like to help gather news—of industry, technology, and people—that's of interest to members around the world, contact editor Murray Slovick at m.slovick@ieee.org for information. Or write to him at THE INSTITUTE, 345 E. 47th St., New York, NY 10017.

Engineers Week, Feb. 20–26

Educating the public on the scope of what engineers do is the purpose of National Engineers Week. This year the 44th annual celebration starts on Feb. 20. The theme is "Engineers turning ideas into reality."

The IEEE is one of some 60 corporate and society sponsors of the week's activities, which this year focus on engineering the future. IEEE members will take part at the grass-roots level, organizing such things as exhibits of engineering projects at local shopping malls and the second annual Future City competition, in which high-school students design a city of the future.

Ideas for projects and ways of organizing local activities are summed up in a National Engineers Week kit available from IEEE–U.S. Activities in Washington, D.C. The kit discusses, for example, how to work with local schools and with local media to publicize an event, and how to put on the mall events themselves. Contact U.S. Activities at 202-785-0017; fax, 202-785-0835; and e-mail, p.mccarter@ieee.org.

Virtual reality and disabilities

Technical and public policy papers are being sought for a conference on "Virtual reality and persons with disabilities," to be held June 8–10 at the San Francisco Airport Marriott Hotel. The object of the conference is to unite experts in virtual reality (VR) with others specializing in disabilities and to promote R&D and commercialization.

Feb. 15 is the due date for papers for the conference, which is sponsored by the IEEE's Neural Networks Council and the Center on Disabilities of California State University, Northridge. For information, contact Harry Murphy, Center on Disabilities, California State University, Northridge, 18111 Nordhoff St., Northridge, CA 91330-8340; 818-885-2578; fax, 818-885-4929; e-mail, vr@vax.csun.edu.

Coming
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ID BIOMETRICS. Hand shapes, fingerprints, iris textures, facial features, voice patterns—these and other personal attributes can be digitized and analyzed by computer to verify identity nearly instantaneously. The process works for everything from corporate security to automated teller machines. In this special report, experts from many leading biometric identification companies describe their latest technology.

NEARING NUCLEAR FUSION. Despite skepticism about whether a commercial fusion reactor based on the magnetic confinement of plasma will ever be built, the last decade has seen noteworthy advances in the shaping, confinement, and control of plasmas. This article wraps up the progress made toward nuclear fusion at installations in the United States, Europe, and Japan.

FAST IN, FAST OUT. Memory designers are always concerned about the bandwidth demanded by fast microprocessors. The speedier static RAMs have managed to keep up, but they are being challenged by dynamic RAMs that have turned to synchronous designs. Jedec has completed a standard and attention is turning to designing the fast synchronous DRAMs into real systems.

PROFILE: MARCIAN E. (TED) HOFF JR. The architect of the first commercial microprocessor and former research chief for Atari Corp. is now a high-tech sleuth, using his collection of vintage electronic components to analyze patent disclosures being contested in the courts.

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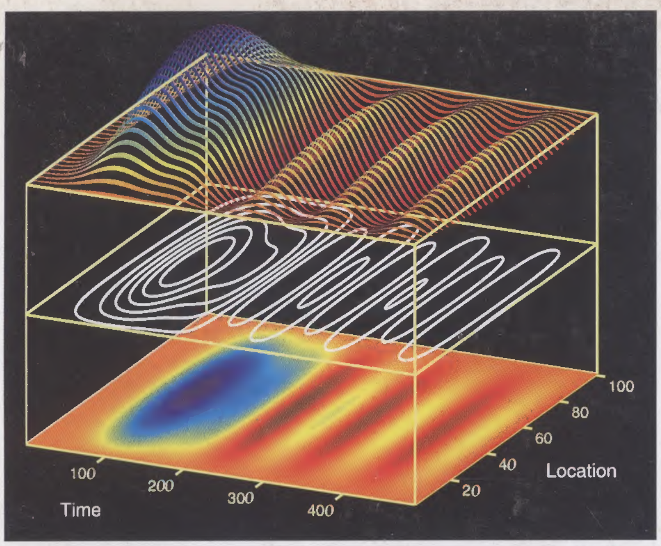

Three views of bending forces on a magnetic levitation train guideway. Analysis was one part of an 80th-order differential equation modeled with MATLAB. Data courtesy of Grumman Corp.

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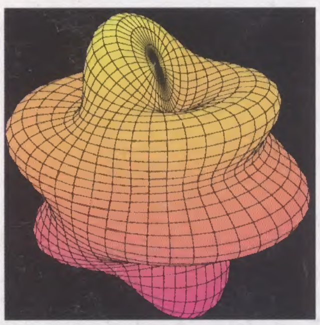

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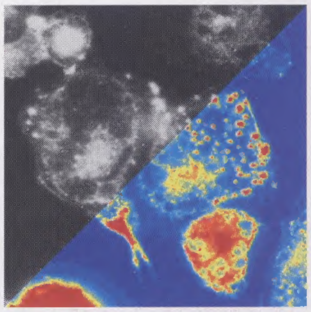

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